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South Africa.

THE incorporation of the two Boer States into British South African territory increases the British possessions on the African continent (including Egypt) to a total of about 3,300,000 square miles, and this includes the richest part—that from north-east to the south—of this great coming land. The French are the next largest territorial power, they having annexed vast tracts of land in the arid, sparsely populated regions of Sahara. From the north to the south of this huge continent the British have established a line of communicating territories, embracing the great coal beds of the Zambesi, the enormous iron deposits of Lake Tanganyika—which has been emphatically pronounced the finest system of natural water-power on earth — through the tropical riches of the central belt, onward through the fertile Bahr-el-Gazahl to the ancient land of Egypt. The war has set the zeal of unification on these vast territories and on British African policy. Henceforth, South Africa will become more and more delocalised, until it merges its distinctive name into that of Federated British Africa, which, stretching from the shores of the Mediterranean to the Southern Indian Ocean, must exercise a dominating influence upon the world.

This fact and the features of the recent pacification constitute the reason why Britain, after a war the greatest in her history since the Napoleonic struggles, emerges from the conflict far stronger than she was before. She is stronger, not only in the estimation of her foreign rivals but in her own. Impressed by the perpetual cries of "decadence"—cries with which FEILDEN'S MAGAZINE has never been associated; there has been shown of late a distinct lessening of national self-confidence. This has been evident in several ways, which it would be superfluous to refer to more in detail here. The material fact is, that this confidence has now returned in its fullest measure. The country is now buoyant, cheerful, with renewed faith in its ability, strength, and resources to meet and overcome every difficulty with which it can be confronted. We are starting on a fresh era in British history, and surely auspices more brilliant have never cheered a new departure.

The problem which is waiting for solution in South Africa is one which has never yet been met with in all the multifarious relations of the British mother-country with her dependencies. South Africa is a country where we shall have to be prepared to meet foreign trade and political competition in its acutest form. This fact, together with the essential characteristics of the country itself, entails a formidable task on British statesmanship; and it is not too much to say, that many of our greatest political leaders look forward to the future with anxiety. In the commercial relations of this country with South Africa no satisfactory analogy can be established between South Africa, as a whole, and any other British possession. With the exception of India, British markets have been mainly provided by those of our own blood, who themselves form the population of the lands they occupy. In South Africa, on the contrary, there is a large native population, together with another white people besides that of British birth or ancestry, who, though now fellow citizens, cannot be expected to weld all at once into that unity we see in Canada—the nearest, though an imperfect, parallel to the South African situation.

The difficulty we are required to face is this:—We have secured the Transvaal and the Orange River Colony at colossal risks and vast expenditure, and in the usual course of procedure these will be

thrown open to the world on equal terms with ourselves. But there is a strong feeling among our merchants and manufacturers that those who have provided the means of securing these markets are entitled to a preferential right to them. Our industrial rivals, on the other hand, are known to have been unremitting in their preparations to displace British trade in its own possessions. Countries like France and Belgium, which exclude British manufactures from their own possessions in the same continent, are preparing to pour their manufactures into our own, and under the fiscal policy which at present rules the commercial system of this country we must look helplessly on while our own markets are swamped with the over-production of hostile rivals. It says much for the industrial energy of this country that we are able to thrust £200,000,000 of our manufactured products every year into the markets of our rivals, in spite of the tariff walls they have built around themselves; but a plea has lately risen for a closer commercial union between the British empire itself, and the peculiar circumstances in South Africa give that plea a special significance at the present time.

In parenthesis, we venture to express the opinion that it is much to be deplored that even the slenderest show of official recognition should be afforded to enterprises formed to take advantage of the political position in South Africa for their own private advantage. We hear of several "Commissions," and other bodies with similar titles, being formed to go out to South Africa ostensibly to ascertain and represent to British manufacturers the industrial circumstances of that country. This is a work, we venture to assert, which is not of a nature to be executed by any private body; and the mere fact of such an enterprise being undertaken under such auspices shows how lamentably the Board of Trade fail in the most elementary duties of their office. The provision of such data is the work of the Commercial Intelligence Department of the Board of Trade, and not of a number of irresponsible persons who must almost infallibly cause more injury than advancement to the interests they are supposed to represent.

Leaving this matter, however, we turn to the question of what is known as "preferential trade," a subject that will shortly be brought into great prominence in connection with the conference of colonial premiers and the home Government, and which is closely associated with the present South African position.

The advocates of preferential trade, of whom there are many, seeing that in the Colonies public opinion is almost unanimous in favour of a rebate to the productions of the Mother Country, have in their minds the possibility of a commercial as well as a political unity of the British empire. Preferential trade, with the more advanced, would be merely a step to an end, *i.e.* free trade within the empire, with a hostile tariff against the rest of the world. The Colonies, however, are not in a position to raise the revenues required for the government and development of their countries by direct taxation; and it is doubtful whether many, or even any, of them would be in a situation to sacrifice their tariffs for many years to come. What the Colonies suggest is, in fact, this:—"If you will give us the control of your market for our food products and raw materials; we will give you the control of ours for your manufactures. This could be done by your placing a small import duty upon all imports competing with Colonial produce; whilst we will grant you, in return, a rebate of so much, upon our existing tariffs."

The objections to this proposal appear at first sight somewhat formidable. The economist, in the first place, might say that such an arrangement is not consistent with sound finance, though that is a point which would well bear debate, since the economist is too apt to regard his science as an end in itself, instead of a means of human development. But undoubtedly the greatest obstacle to any scheme for developing colonial trade with the Mother Country, comes from the apparently unshakeable determination of the political powers of this country, not to permit of any step which will have the effect of interfering with the principle of Free

Trade. "A preferential tariff arrangement with the Colonies," they say, "would entail a tax upon food and raw materials. That again, would entail an advance in the cost of manufactured articles, so that our export trade with foreign nations—twice greater than that with the Colonies — would fall away, to the injury, not merely of manufacturers but of the mercantile service, and the enormous banking and exchange business which depends upon this traffic. Moreover, the people of this country could never be brought to consent to any enactment which would have the effect of permanently increasing the cost of their food."

Pro and Con.

Against this it is retorted that the rapid extension of our Colonial markets in a short time would fully compensate us for any loss of trade in other directions; whilst the priceless advantage of securing a safe, dependable supply of food from our own Empire would be an ample return for a possible increase in the cost of food and raw materials, too microscopic in proportions to be practically discernible.

There can be little doubt there is, what may be a slow, yet, at the same time, a steady, revulsion of opinion in this country on the subject of the fiscal relations with the British Colonies. The dissatisfaction aroused by the frantic struggles of our industrial rivals to get in first to a market which we have the right to hold to ourselves against all comers is both widespread and deep.

We beg to express the conviction that unless some kind of preference is afforded to British manufacturers in the Transvaal and Orange River Colony, we shall have simply opened up at stupendous expenditure new markets for the benefit of our rivals. We have had to pay for the war, and are entitled to some preference in our own markets over nationalities who, during its continuance, took every opportunity of expressing their hostility to this country and their sympathy to those who, at that time, were our enemies.

The Metric System.

THE necessity of abandoning the antiquated medley of unconnected units which compose the official system of weights and measures still in use in this country has for many years past been fully grasped, and put forward with untiring energy, by a few of our leading engineers and physicists. Unofficially, much progress has been made in the employment of the metric system, which has been officially adopted by every civilised nation, with the exception of Great Britain, the United States, and Russia. Russia, moreover, has gone so far in the direction of its adoption that it may practically be excluded from the list. All our accurate scientific work is now recorded in this system, and it forms the basis of all the measurements pertaining specifically to the great and growing industry of electrical engineering.

In this respect, indeed, we have no cause for self-reproach, for the system of electrical measurement which is in universal use is the outcome of the labours of the British Association Committee on Electrical Standards.

In spite of this, however, and in spite of a Parliamentary Committee having reported in favour of adopting the metric standards, we still officially retain our ancient medley.

If we delay much longer we shall be the *only* civilised nation which does not officially use the metric system; for our American cousins are now fully alive to the disadvantages entailed, in competition for the markets of the world, upon the users of standards which are not generally recognised.

The leading part in pressing this matter forward in the United States has been taken by the Franklin Institute, of Philadelphia. From a paper read before this institution last November, by S. W. Stratton, the Director of the National Bureau of Standards, and published in the Journal of the Institute for February, we quote the following paragraph:—

"Whatever may be said of the advantages to be gained by the adoption of uniform and correct standards in any country applies still more in regard to uniformity of standards between nations.

The introduction of modern methods of transportation and communication have brought the countries of the world into closer relation than were the counties of Great Britain a century ago, and while the question of a universal system of weights and measures has been discussed for many years, the adoption of such a system has become a necessity at the present time. The choice of the fundamental standards for this system is a matter of convenience, but that it be a decimal system is of paramount importance. The metric may be no better than the yard, but the metric system is a decimal system."

His paper concludes with a sentence which, in common with the quotation which we have given above, we heartily endorse.

"There is no doubt," says the author, "in the mind of any thinking person but that a universal system must soon be adopted, and no system offering advantages equal to that of the metric system has yet been devised."

The March issue of the same journal contains the report of the special committee appointed by the Franklin Institute to consider the feasibility and advisability of the adoption of the metric system in the United States.

The conclusions arrived at by the committee are as follows :—

"Whereas, It is desirable to obtain an international standard of weights and measures, also to simplify and regulate some of our existing standards ; and

"Whereas, The metric system is commendable, not only as a suitable international standard, but also for facility of computation, convenience in memorising, and simplicity of enumeration ;

"*Resolved*, That the Franklin Institute approves of any movement which will promote the universal introduction of the metric system with the least confusion and expense.

"*Resolved*, That the National Government should enact such laws as will ensure the adoption of the metric system of weights and measures as the sole standard in its various departments as rapidly as may be consistent with the public service."

The report was adopted by a decisive majority, after a protracted discussion and the consideration of a large amount of correspondence from prominent manufacturers and professional men throughout the States, whose opinions on the report had been solicited. We shall refer again to these as soon as they are published.

A Bill is now before the Congress of the United States with the object of bringing about the reforms advocated above, and our ably conducted contemporary the *Electrical World and Engineer*, of New York, recently suggested that—

"The ideal method would be for the United States to enter into an agreement with Great Britain and her Colonies, whereby, on and after a certain date, the existing medley should be replaced by the metric system in all official documents, both here and abroad, by mutual consent."

This is a proposal which we should most heartily endorse, if it be not already too late, for the Committee on Coinage, Weights, and Measures, to whom the Bill was referred, presented on the 21st of April last a long and interesting report in favour of a Bill of which the text is as follows: "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That on and after the first day of January, 1904, all the departments of the Government of the United States, in the transaction of all business requiring the use of weight and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, 1907, the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States."

Lord Kelvin, during his recent visit to the United States, was asked to give evidence before the Committee, and, in complying with the request, strongly advocated the introduction of the metric system. Want of space prevents our considering more than a few of the most important points of the report, which is of the greatest interest throughout to all who are in any way concerned either with international trade or with education—in other words, to all thinking men. It is reproduced in full in *Science* of May 23rd.

It is pointed out that the great difficulties which seemed to stand in the way have been overrated, for its introduction

into Germany, Austria, and other European countries was accomplished with little or no confusion. Estimates made by the Department of Education and others show that the work of at least two-thirds of a year in the life of every child would be saved by the adoption of the metric arithmetic; and the Committee call attention to the fact that the British Parliamentary Committee having in charge a similar investigation estimated the saving of time at one year.

This is a point that should be insisted upon by those who are endeavouring to bring this reform about. It would probably be difficult to arouse any great enthusiasm among our unthinking masses by even the most skilful and convincing exposition of the advantages which such a reform would confer upon our exporters. The possibility, on the other hand, of shortening the term of compulsory attendance at school by from nine months to a year would appeal to them in the strongest fashion.

In considering the necessity of the metric system from the point of view of international commerce, the opinion is quoted of the president of the National Manufacturers' Association of the United States to the effect that "wherever manufacturers undertake to extend their trade in foreign countries, they encounter the Metric system, and it is the only system of absolute uniformity which prevails throughout the world"; and that of the director of the Philadelphia Commercial Museum, who states as his belief that "millions of dollars are lost every year in transporting our weights, measures, and money from that of one country to another in our international business relations."

It is not suggested in the United States, and we would not suggest here, that any compulsion should be exercised. If the change were made officially, the new system would be rapidly adopted by all our more far-seeing and energetic manufacturers, and the others would gradually learn the disadvantages to themselves of continuing in the old rut. It would probably be many years before the metric system became universal among the smaller retailers and in remote villages, but it would gradually spread from the manufacturers to the larger retailers, and then filter downwards, and it certainly appears to us that a change which must, in the nature of things, come sooner or later, would thus be effected in the manner which would cause the smallest possible inconvenience.

It is certainly not to our interest to lag behind the United States in this matter. Our manufacturers have for a long time felt the inconvenience of our insular system in catering for the European markets, and the more enlightened ones have already gone some considerable way in adopting the new system for export goods, while retaining the old for home consumption. This inconvenience will be greatly intensified if the new system becomes the official one in the United States while we are still clinging to the old one.

The Triumph of British Locomotives.

FOLLOWING up the remarks we made on this subject in our last issue, we do not agree with the opinion expressed in Lord Cromer's report that "the British weak point is the time required for executing orders": it is an expression that is scarcely consistent with essential points mentioned in that document. A great deal of nonsense is often talked about the dilatoriness of British firms, especially by people who are ignorant of the facts. Without considering the restrictions entailed by Government methods of inspection in Great Britain, it is perfectly manifest from the contents of Lord Cromer's report that under a given specification both American and Belgian makers might be able to finish a batch of engines more quickly than British makers, because both of the former put very much less work on their engines, the Americans avoiding the expenditure of time in the proper finish of details, and the Belgians neglecting workmanship that ought to be employed in making the materials harder and more durable. Under these circumstances it is just as absurd to complain of

delay as it would be to find fault with a firm of conscientious contractors for not executing work with the celerity of a "jerry" builder. The real source of the trouble is to be found in the improvident and hand-to-mouth methods of most Governments. They generally neglect the ordering of locomotives for years, and then suddenly discover that traffic cannot be continued unless a large number can be procured within an unreasonably short space of time We have lately drawn attention to an example of this improvidence in India, and the following extracts show that very similar conditions have prevailed in Egypt. Thus we learn that "from 1895 to 1897, for financial reasons, no locomotives were ordered; while during the same period large extensions were opened and the traffic increased nearly 20 per cent., with the result that it became urgently necessary to order some 70 engines." Mr. Trevithick then reported that "while he did not consider the American design suitable, he could not undertake to work the traffic for eleven months without additional engines." Next we read "at the end of 1899 we were still alarmingly short of locomotives," and "for various reasons no goods engines were ordered." These extracts show that a state of urgency had been allowed to develop, and the result was that British quotations, based on the official specifications and the usual restrictions as to quality of material, inspection, and finish, were flung aside, and contracts were made for American engines, without any stipulation as to design, inspection, or finish. The only safeguard was a promise from the American firm that the engines would "be of equal power and equally suitable to the work which had to be performed," and this promise was apparently accepted in the face of the opinion held by Mr. Trevithick that American designs were unsuitable. We now learn from the report that the engines supplied were not, as alleged by the makers when tendering, of equal power and equally suitable for the work with the designs put out to competition. This is quite what might be expected, but we do not think it affords any reasonable basis for unfavourable comment on British "delay."

With the view of showing what can be done in the way of prompt delivery by a British firm when conditions are comparatively favourable, we may mention the following facts, furnished by Messrs. Dubs & Co., the well-known locomotive builders, of Glasgow:—"On Sept. 2nd, 1895, we got an order from a Colonial Government for eight heavy engines and tenders. These were shipped and invoiced on December 26th and 31st, 1895, and January 16th, 1896—that is, completed in practically four months from the date of order. On October 11th, 1895, we received an order for five more of the same engines, and these were delivered on February 4th and 13th, 1896—that is, in less than four months, though the New Year holidays intervened. On Oct. 21st, 1895, we had an order from the same Government for eight still heavier engines and tenders of a different type, and these were delivered between April 11th and 28th, 1896; and in June, 1896, we received from the same Government an order for 40 engines and tenders, all of which were delivered between December, 1896, and June, 1897." From the above it may be gathered that people are entirely at sea who write as if American builders can produce engines in as many weeks as British builders require months. No doubt many of our leading firms are full of orders, and this may tend to retard deliveries to some extent; but so far as Government requirements are concerned, the great difficulty is to be found in demands for variations of detail and design, and in the system of inspection adopted.

The chief reforms to be desired are the abolition of middlemen in the form of consulting engineers and inspectors, and the elaboration, by the leading locomotive experts, of standard tests for materials and standard designs for working parts, leaving each builder free to introduce such modifications of general design as might be dictated by experience or that would be necessary for complying with varying traffic conditions. As things stand, Government officials and engineers hinder the builder, and then complain of the resulting delay.

Original Signed Articles

Some Notes on British Bridgework.

By W. H. THORPE, A.M.Inst.C.E.

FACSIMILE OF A TOKEN STRUCK IN COMMEMORATION OF THE COMPLETION OF THE IRON BRIDGE AT COALBROOKDALE.

THE engineers of these islands were the first to introduce successfully the use of metallic bridges. Passing by an attempt in 1755 to apply cast-iron to the building of a bridge at Lyons, of which one rib was set up in the founder's yard, the project being then abandoned, the earliest structure of the kind brought to a more or less successful completion is that at Coalbrookdale, a span of 100 ft. This bridge, of which the foundation was laid in 1769, though the date of the design executed, prepared by Thomas Pritchard, of Shrewsbury is 1775,w as not completed till 1779; and it may well be questioned whether the proposal to use iron was seriously entertained at the commencement. The ironwork was supplied by Abraham Darby, of the Coalbrookdale Works; a local ironmaster, named Wilkinson, said to be "iron mad," and who prophesied the general use of iron for bridges, ships, and houses, being a very strong advocate of the innovation. It was, indeed, largely due to his insistence that this material was adopted, Pritchard having been instructed to prepare his designs accordingly. It is of interest to note a legend exists, to the effect that as the ironwork was in process of erection, a strolling fiddler passing that way was assailed by the men engaged with rough chaff. The musician vowed that if they did not desist he would "fiddle the bridge down." Derision following this vain boast, he set to work, soon found a note to which the ribs seemed to respond, and

applying himself vigorously, with judgment timing his efforts to produce the greatest effect, soon had the structure in such a state of tremor that the workmen at last begged him to forbear. This story may be a fabrication, we cannot vouch for it, but the fact that it obtained currency shows clearly the nature of the apprehensions entertained by the critics. Unfortunately, the abutments of this bridge closed in to some slight degree, and did damage to the ribs, but not to the extent of causing its destruction. Following this was an endeavour made by Thomas Paine, the many-sided author of the "Rights of Man," to secure the construction of a cast-iron arched bridge over the River Schuylkill; he prepared designs and a model in 1787, which, after being submitted to the Pennsylvania Assembly, were taken to Europe, laid before the Academy of Sciences in Paris, and then brought to England, a contract being ultimately placed with Messrs. Walker, of Rotherham.

OLD CHAIN CABLE BRIDGE AT MIDDLETON IN TEESDALE; ERECTED 1741.

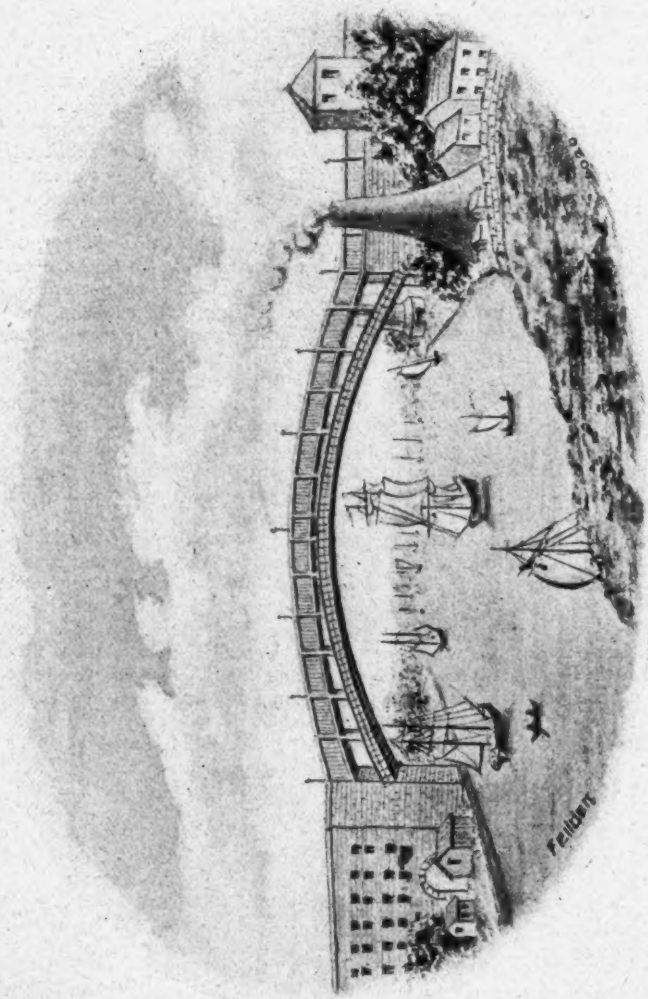
After erection temporarily at Paddington Green, and remaining on view for some time, there appear to have arisen financial difficulties, following the death of a colleague, the ironwork never reaching its original destination, though it is said to have been used in the bridge of 236-ft. span over the Wear at Sunderland, completed in 1796; but this is probably true of the metal only, as Payne's bridge is alleged to have been broken up. Both the Coalbrookdale and Sunderland bridges, it is noteworthy, have outlived many more modern constructions.

Of early suspension bridges little can be said. The idea is extremely ancient; it is almost impossible even to assign a date for any such example having a metallic cable, which may be said to be the first having this peculiarity. It is, however, worthy of remark that a suspension bridge of chain cable, 70-ft. span, stretching between rocky banks, was set up over the River Tees at Middleton in the year 1741 for the use of miners, and remained in existence over 80 years, though an accident occurred in 1820, when one of the cables broke.

The first example of a cast-iron railway bridge came into existence in 1823, upon the Stockton and Darlington Railway under the direction of George Stephenson; this was not removed till last year. From the very infancy of railways, indeed, cast-iron was very largely employed for bridges, some extraordinary examples being erected before the very necessary control of the Board of Trade tended to bring practice to some uniformity in the matter of limiting stresses.

A serious disaster in 1847 to a new bridge over the Dee at Chester—of which Robert Stephenson was the responsible engineer, and consisting of three spans of 98-ft. clear, each span having cast-iron girders in three lengths, bolted together and trussed with wrought-iron rods—largely

contributed to check the almost unlimited confidence of engineers, and to precipitate legislative interference. It is easy to be wise after the event, and with present-day knowledge, the temerity of the early engineers is a little astonishing. Telford, for instance, seriously proposed to span the River Mersey at Runcorn with cables made up of $\frac{1}{2}$-in. square wrought-iron rods, of 27 tons per square inch ultimate strength, stressed in work to close upon half that amount. At the inquiry following the Dee Bridge accident, one witness stated it had been an established rule in



VIEW OF THE BRIDGE OVER THE WEIR, SUNDERLAND. TAKEN FROM AN OLD CHINA BOWL.

practice that from one-third to one-fourth of the breaking load was considered the safe load using the larger fraction for the smaller bridges. This is quite contrary to later usage, and probably resulted from a distrust of large castings.

Touching the first use of built-up wrought-iron girders, Wm. Handyside, in 1847, addressing a meeting at the Institution of Civil Engineers, said that in St. Petersburg cast-iron girders, in buildings, had for some years been abandoned in favour of wrought-iron girders, consisting of several plates riveted together, and having angle-bars at the top and bottom on both sides. A beam of this kind, it is evident, would be intermediate in type between the rectangular beam and flanged girder, and it is probable that the angle-bars were first used to give lateral stiffness, as Mr. Handyside refers to the necessity for insuring this. It is apparent that in these angle-bars we have the rudimentary flange. As a digression, it may be noted that this engineer did much important work in Russia, which, had it been executed in this country, would no doubt have made him more famous. His most startling achievement was the raising of a granite monolith of 12 ft. diameter, 84 ft. high, on a base 30 ft. above the ground, which was accomplished in 25 minutes.

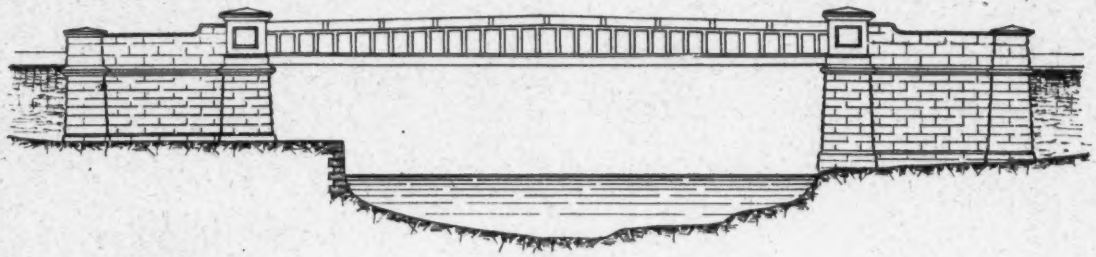
As the firstfruits of the inquiry instituted with respect to the Britannia Bridge tubes, in 1847 the first wrought-iron box girder bridge was constructed for Vignolles by Wm. Fairbairn, to carry the Blackburn and Bolton Railway over a canal. The clear span was 60 ft., and consisted of three such girders, with a suspended timber floor. This bridge has now been replaced by a more modern structure.

In all this English engineers took the lead, some with care, others boldly blundering to a better knowledge of their craft.

From that period forward the development of bridge design in this country has slowly proceeded; for many years—it is almost heresy to say it—the tendency, perhaps, was to design bridges with the minimum of precise knowledge that might be supposed sufficient, except in a few notable instances, in which the preparation of drawings for any unusual work was preceded by exhaustive study; but once an example had become established, it was the model for many others. This may be justified so long as no advances are made, but the system has been carried to the extremity of conservatism.

The need for improvement in design has been the less apparent because the engineering of new works, and the maintenance of old have commonly been conducted by entirely different bodies of men, the experience of the one has not been made available to the other, to the extent desirable, and neither have been in close touch with the manufacturer. The three controlling influences in the cost and durability of bridgework, design, manufacture, and maintenance, have generally in this country, by an almost complete separation, but little effect one on the other, though it is manifest a knowledge of all three is necessary to insure good results.

The ordinary bridgework of English railways is, too, so small, and the conditions as to span, angle of skew, and construction depth so various, that it is difficult to do much in the way of standard designs. Even for the same railway, each case is dealt with on its merits, or, to be correct, is supposed to be so dealt with, and though any one case *may* get a fair amount of attention, it certainly has less study devoted to it than might reasonably be expected if the particular span had to be repeated 100 times. The infrequency of repetition work, in which it is manifestly desirable to bestow great care on detail, checks the development of systematic economy in design. And, as a rule, it is only in particular instances where there is on the designer's part a strong personal instinct towards economy that the attempt is made. It may reasonably be questioned how this limited view of the matter affects the general question of British bridgework abroad, as well as at home, but it is to be considered that the methods applied to the design of bridgework for abroad are not so very dissimilar to those applied to home work. The designer quite possibly



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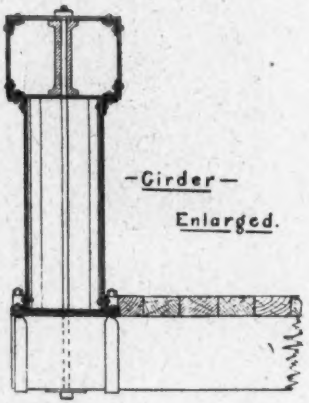

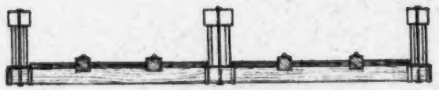

— Cross Section. —

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BRIDGE OVER LEEDS AND LIVERPOOL CANAL—CARRYING THE BOLTON TO BLACKBURN RAILWAY.

details thousands of tons, which he never sees either in the yard or on the site, and of the after history of which he knows nothing.

There is an idea somewhat prevalent that economy in detail, simplicity of parts, disuse of smithing, and moderate riveting, make no difference in the cost to the buyer; that it does not show at so much per ton; but it is apparent, other things being equal, that the engineer who produces designs to be carried out at a low shop cost, must in the end, when this becomes known, get cheaper bridges than would otherwise be the case, though it may not be manifest in any and every contract.

It may be conceded, however, that no amount of skill devoted to design by consulting engineers, and their expert assistants, can result in the production of bridges costing so little and produced so quickly as those which with equal skill may be made under the American system, in which each manufacturer, while limited by a rigid specification to ensure that he confines his attention to legitimate economies, tenders on his own design. To adopt that procedure in this country would completely disorganise our present routine, upset both engineers and makers alike, and though it may come to that in time, it need not, if our present methods, cumbersome and wasteful, are improved; retaining the one advantage our system possesses, that the engineer has his own designs carried out, not those of a manufacturing firm.

It is not to be denied that, however excellent the work of first-rate American firms may be, the not uncommon practice in that country of leaving so much to the maker, without efficient and independent professional control, has resulted, and still does result, in an extraordinary number of bridge failures, a record without a parallel in any other country.

W. B. Thorpe

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A Short Cut to the Metrical System.

By HENRY E. P. COTTRELL, A.M.Inst.C.E.

A GREAT deal has been written concerning the superiority of the metrical system from the practical standpoints of ready-reckoning and book-keeping, when compared with the *omnium gatherum* system of weights and measures in the midst of which we have grown up. The undeniable good points of the metrical system are almost wholly due to the uniformity with which it covers the vast area of mensuration, the simple interrelation of the various units of which it is composed, and the practical way in which the whole system of weights and measures is based on the decimal notation, and on a single arbitrary unit of length. The question whether the deliberate choice of the French *savants*, at the end of the eighteenth century, of the meter as that arbitrary unit would be endorsed by even their national successors, let alone by a congress of world scientists of the present day, has long become one of purely academic interest. This is the case, in spite of certain obvious advantages which would attach to the adoption of a standard more exactly correlated with the units, which have sprung up around the nineteenth-century notion of work, which could have been met, for example, by making the meter 21·976 millimeters shorter or calling the acceleration per second due to gravity at the equator ten standard units of length.

Such questions may safely be relegated to the same corner of our reference library as the fascinating speculations as to the existence of an imperial single-unit metrical system side by side with the commercial multiple-unit systems in ancient Babylon, and the great Pyramid system of units derived from the dimensions of our globe itself.

Whatever might be our choice of units, could we start afresh with a clean slate, the circumstances which we have now to face remain practically unaltered. The metrical system, with its arbitrary standard meter, has been adopted by such a large section of the world's inhabitants, by such a large proportion of people with whom we must maintain trade relations, that as reasonable business men we must, in the interest of our foreign trade, endeavour to alter our standards in conformity with the views of our customers. Furthermore, if we consider the endless multiplicity and wearisome complexity of the units for weights and measures which were in current use throughout Europe before the introduction of the metrical system, the universal approval with which it has been received can be no matter of wonder. A good deal of our disinclination and distaste for the change which we see looming in the distance doubtless arises from the fact that we have been sensibly emancipated from a proportion of the multiplicity and complexity of our good old weights and measures by the imperial standards, which simplified and did away with so many of them. Were it otherwise, we should be among the first to say that life is too short in the twentieth century to carry on trade under the conditions they imposed.

Each trade and each occupation in the good old days seemed to take a special pride in possessing its own exclusive system of units, bearing special distinctive names, and more or less wholly unrelated to the units adopted by other trades and occupations. It should be remarked, in passing, that the practice of adopting distinctive names to indicate units used in connection with special branches of science has been followed in the modern scientific world almost as universally as it was followed by the mediæval guilds and professions in their special branches of trade and commerce. Their difference lies in the correlation and inter-dependence of

the various units in the one case and their isolation and independence in the other, while their likeness lies in the recognition of the fact that a nomenclature must be distinctive just as the selected unit must be readily applicable or handy—to subserve the use for which they are required. Unquestionably the error of the good old days consisted in the absence of systematic correlation between the units of measurement used for the various trades and professions, rather than in the redundant nomenclature. Those who have not had occasion to look into the question of nomenclature rather closely would be surprised to find that the exigencies of trade requirements have to a relatively considerable extent marred the uniformity and simplicity of metrical nomenclature, and introduced redundancy and complications strangely akin to our own. The inherent absurdity of measuring, say, earth, beer and grain by the uniform standard of a cube yard, instead of by that in the first case and the gallon and the bushel in the other two cases, has been thoroughly recognised, the result being the introduction of two supplementary standards with decimal multiples and divisions—instead of millesimal ones—to meet the case, one founded on the stere or cubic metre, the other on the litre = cubic decimetre. (*See* Table XII.). The same thing has occurred in square measure, where one supplementary standard with decimal multiples and divisions has been added to the square meter with the centesimal divisions—to wit, the are or square decametre (Table XI.). In the case of weight, where the standard unit represented is relatively too small a quantity for even its multiples to conveniently meet the requirements of railways and shipping, two new distinctive names had to be adopted, the quintal and the tonne. While in the ordinary trades supplying food stuffs a unit (the litre) was retained with the non-decimal divisions of $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$, which was too handy to be discarded, the fact being that for ordinary everyday purposes the human brain and its minister the human tongue demand other qualities besides universality, uniformity and simplicity in the nomenclature of the standards of measurement humanity has to use. A measure, and especially its verbal token or name, must be distinctive, *i.e.* capable of easy recognition, to be of real avail for ordinary use. And these distinctive names must represent tangible units well suited to the special purposes for which such units are intended and required. Theoretically it is doubtless admirable to embody the idea of the basal units of length, area, and capacity, and weight, each in a single distinctive name, and label their divisions and multiples with prefixes which should indicate instantly and unmistakably their relation to their respective units and each other. In practice, however, such a system may prove both clumsy and inapplicable, for the selection of a unique basal unit in each case which will suit the whole range of measurement is an impossibility. Again, ascending and descending scales of magnitude, on the basis of ten, must inevitably prove in some cases too rapid and in others too slow to meet special requirements. These defects of scale entail either acquiescence in the use of long compound words expressive of intermediate values or the introduction of subsidiary names for special magnitudes, inexpressive of any correlation of units but unavoidable in practice. Here is a legitimate case where simplicity and ideal perfection may be called upon to give way to handiness and expediency. The admirable and timely paper read by Mr. Arthur Greenwood at the Glasgow Meeting of the British Association last year elicited a useful and practical discussion on the question of the adoption of the metrical system, which showed what great strides have been made since 1864, when legislative permission was accorded to the use of these measures. The question has now almost entered the stage of practical politics in the commercial world, and the external pressure exerted by loss of commerce in neutral markets, through remaining wedded to our insular system, cannot fail to bring it prominently forward before long.

But to return to our own pet measure, no one who is accustomed to its use can deny that there is an inherent handiness in the length of the British 2-ft. rule

which is superior to the 3-ft. rule of Scotch workmen or the ½-meter measure met with on the Continent. This is doubtless due to the fact that the length of the 2-ft. rule represents the average result of the transmission through the ages of the cubital foot of Egypt and digital foot of Greece, which reached us through half-a-dozen different sources and at intervals of centuries. The inch and its divisions into vulgar fractions of the powers of two are inherently more handy than the decimal sub-divisions of the meter, as all those who are equally at home with both will generally acknowledge, to which fact abundant evidence is afforded in the history of comparative metrology.

The chain in land measure, apart from its relation to the acre, is almost equally handy for its special purpose as the 2-ft. rule. In this connection it is noteworthy that this inherent handiness has been recognised among the users of metrical measures by the adoption of the double decametre (20 meters) for survey purposes, which is identical in length (within 6 per cent.) with our chain; while the hundredth part thereof, or double decimetre, which bears the same relation of actual length to the link, for similar reasons replaces our foot in the foreign drawing office. The moral is that if we must adopt the metrical system, and it seems indisputable that we ought, we can and should do it without sacrificing more of the inherent handiness and distinctive character of our own weights and measures and their nomenclature than is absolutely unavoidable.

The United States of America have paved the way to the adoption of the metrical system by decimalising the inch and the ton, while our own Colonies have, in many cases, done the same by adopting the "line" or 100-foot unit, the "square" of 100 square feet, and the "cube" of 100 cubic feet, and nearer home engineers and surveyors have worked in the same direction by dividing their levelling staffs into feet and tenths. If we must swallow the pill, let it be compounded of all the essential ingredients pertaining to the metrical system—and especially the underlying arbitrary unit on which it is based—but let it be put up and labelled in British fashion to suit our own predilections, while not neglecting the convenience of our customers. In other words, let us keep the names we are used to, and let them signify metrical values as closely equivalent to the values which have been evolved in these islands from the common metrical stock of antiquity (which use has made acceptable and association has endeared) as it is possible, so that the transition may be hardly perceptible. In so doing we shall be following the precedent set us by our Teutonic friends, who are nothing if not practical, and who were most probably wholly uninfluenced by Gallophobia, in rejecting the French system of nomenclature in favour of one more German in character. For these reasons we do not feel at all disposed to agree with Mr. Greenwood's objections on the score of confusion, or with his suggestion that it would be a favourable opportunity for paying a graceful compliment.

In scientific circles at home, as well as abroad, the metrical system and its nomenclature is already universally adopted; and its extension to the field of semi-scientific pursuits and professions is assuredly only a question of time. The imperative necessity for the free interchange of data derived from experiment, and for the mutual understanding of theories evolved therefrom without cumbersome reductions to different scales of units, compels uniformity. Were it possible to dissociate even to a moderate extent the manufactures for foreign markets from those intended for home consumption, then it probably might be possible without detriment to our commercial interests to continue aloof from the majority of our customers in our insular standards of mensuration, but this is not possible.

It is simply impracticable to have two sets of patterns, two sets of templates and jigs and two sets of scales and gauges in the same factory—any attempts in this direction can only eventuate in endless complications, errors and expense. The present patterns and other manufacturing paraphernalia would, no doubt, in any case, lapse and become obsolete with time, and new designs may be required to pave the way for the coming change, but

TABLE I.—PROPOSED NEW VALUES FOR OLD NAMES.

Long Measure. For ordinary purposes.

Metrical Value.	Inch.	Hand.	Yard.	Rod.	Pole.	Mile.	Difference from old measure, per cent.		Difference in actual length	
							+ Increase.	− Decrease.	+ Increase.	− Decrease.
Metres.										
0·025	1	...	...	...	...	...	...	1·5748	...	0·0157ins. = 0·4mm.
0·1	4	1	...	...	...	...	...	1·5748	...	0·0629ins. = 1·7mm.
1·0	40	10	1	...	...	...	9·3613	...	3⅜ins. = 85·65mm.	...
10·0	400	100	10	1	...	...	1·89 times as long.	...	14·69ft. = 4·97m.	...
100·0	4,000	1,000	100	10	1	...	18·88 times as long.	...	311·59ft. = 94·97m.	...
1000·0	40,000	10,000	1,000	100	10	1	...	40·9305	...	720·38yds. = 609·315m.
Metrical Equivalents.	Quarter of a Decimetre.	Decimetre.	Metre.	Decametre.	Hectometre.	Kilometre.				

NOTE.—The new metrical inch, fixed at 0·025 m., would be for all ordinary and non-scientific forms of measurement indistinguishable from the present inch. The scale of identity of the new rod, pole, and mile with the old units would unfortunately have to be lost, as the kilometre and old mile are so far apart in size. The familiar words, "rod," "pole," and "perch," of identical value, are almost obsolete in use, and might therefore be used to denote unidentical values of a different scale of magnitude without inconvenience.

we cannot afford to wait if we mean to hold our own in the foreign markets of the world, either the necessary time or the inventive evolution involved.

There is no question that the time has arrived when the leaders of the various trades should take the courage of their convictions in their own hands, and recognise in a positive, practical fashion the advantages of the metrical units. This recognition might well take the form of a convention, ratified by the Chambers of Commerce, to adopt permissively an inch of 25 millimeters, a foot of 300, and a yard of 40 of these new inches (= 1 meter). In selecting a foot commensurable with metrical units, there would evidently be the choice of two alternatives, viz. the foot of 12 new inches or 30 centimeters in length, shorter by 1·5748 per cent. than the present foot, or a foot of one-third of a meter, which would be longer by 9·3613 per cent. The latter in addition would possess the serious disadvantage of being decimally incommensurable. In a similar way, the Colonial "line" of 3 new rods (= 30 meters) would be preferable to one of one-third of a new pole, and closer to the original length. The proportionate variation in the prime cost of sales effected by the new inch and foot would be about ¼*d.* in the shilling and 4*d.* in the pound, as against the old measures, while with the new yard there would have to be a relative increase of 1½*d.* in the shilling and 1*s.* 10½*d.* in the pound. In surveying, where it is evidently desirable for the coincidence to be closer, the preserved identity would be within 0·5797 per cent., or about one-half a link in the chain. For further details of the proposed changes, we would refer our readers to Tables I. and II. In square measure, the essential unit with us is the acre, with its relation to the chain. The latter is maintained, but the area of the former would have to be diminished by 1·1564 per cent. to make the new acre exactly two-fifths of the hectare. Curiously enough, the new rood, a quarter of the new acre and one-tenth of the hectare (equal exactly to the decare), would remain identical with the old rood, within the same limit of

TABLE II.—PROPOSED NEW VALUES FOR OLD NAMES.

Long Measure. For Surveying.

Metrical Value.	Hair.	Nail.	Digit or Finger or Ring.	Link or Span.	Fathom.	Chain.	Furlong or Cable.	Knot.	Difference from old measure per cent.		Value of Measures compared.		Difference in actual length.	
									+ Increase.	− Decrease.	In old inches.	In new inches of 0·025m.	+ Increase.	− Decrease.
Metres.														
·0002	1	...	...	...	...	...	...	...	...	...	·0078741	·008	...	...
·002	10	1	...	...	...	...	...	...	...	...	·0787408	·08	...	...
·02	100	10	1	...	...	...	...	...	...	...	·7874086	·8	...	...
·2	1,000	100	10	1	...	...	...	.	...	0 5766	7·92	8	...	·00571ks. = 1·116mm.
2·0	10,000	1,000	100	10	1	...	...	..	9·3613	...	72 0	80	6⅔ins. = 171·3mm.	
20·0	100,000	10,000	1,000	100	10	1	...	...	...	0·5766	792 0	800		Chain. ·5766lks. = 0·116m.
									Cable.	Furlong.			Cable.	Furlong.
200·0	1,000,000	100,000	10,000	1,000	100	10	1	...	7·8789	0·5797	7920·0	8,000	47·907ft. = 14·607m.	3·53ft. = 1·16m.
									Geog. Mile.				Knot or Geog. Mile.	
2,000·0	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	7·8789		72,991·92	80,000	146·02m. = 479·07ft.	
Metrical Equivalents.	Double Dixmilli-metre.	Double Millimetre.	Double Centi-metre.	Double Deci-metre.	Double Metre.	Double Deca-metre.	Double Heca-metre.	Double Kilo-metre.						

NOTE I.—The proposed new knot would be a close mean between the old Irish and Scotch miles in length, and close to the $\frac{1}{20000}$ of the equatorial circumference of the globe.

NOTE II.—The names "hair," "nail," and "digit," "finger," or "ring" have a familiar ring, but no longer possess a value in practice, with the exception of the last, which in the surveyors' chain possesses about the proposed value of $\frac{1}{10}$ of a link. To reduce to metrical values, take the link as unity and divide by 5 or the fathom and multiply by 2.

TABLE III.—PROPOSED NEW VALUES FOR OLD NAMES.

Square Measure. For ordinary purposes.

Metrical value.	Square Hand.	—	Square Yard.	—	Square Rod.	Rood.	Square Pole.	—	Square Mile.	Difference from old measure per cent. + Increase.	Difference from old measure per cent. − Decrease.
Square Metres.											
0·01	1	...	...	...	...	...	...	...	..	...	3·101
0·1	10	1	...	...	...	...	...	...	...	...	...
1·0	100	10	1	...	...	...	...	...	...	19·603	...
10·0	1,000	100	10	1	...	...	...	...	...	... times	...
100·0	10,000	1,000	100	10	1	...	...	...	..	3·954	...
1,000·0	100,000	10,000	1,000	100	10	1	...	...	...	...	1·1565
10,000·0	1,000,000	100,000	10,000	1,000	100	10	1	...	...	...	...
100,000·0	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	...	...	...
1,000,000·0	100,000,000	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	...	61·389
Metrical Equivalent.	Square Decimetre. Dixmilliare.	Milliare.	Square Metre. Centiare.	Deciare.	Square Decametre. Are.	Decare.	Square Hectometre. Hectare.	Kilare.	Square Kilometre. Myriare.	—	—

NOTE.—The old rood is 1,011·7 square metres, or within 1·1565 per cent. of the decare; 2½ acres are similarly within the same percentage of excess equal to the hectare. The new acre would remain = 4 roods = 10 square chains, as at present.

To reduce to metrical units (metres), take square yard as unity and progress by 100; or to "ares," take square rod as unity and progress by 10. To reduce new acres to metrical measure metres, multiply by 4 and shift decimal point three places to the right; and to ares (square rods), multiply by 4 and shift decimal point one place to the right.

TABLE IV.—PROPOSED NEW VALUES FOR OLD NAMES.

Measures of Capacity. New Wine and Beer Measures.

Metrical Value.	Gill.	Quart.	Pin.	Kilderkin	Tun.	Difference from old measure, per cent. + Increase.	Difference from old measure, per cent. − Decrease.	Difference in value. In the £	Difference in value. In the Shilling.	Approximate Value of new Measure as compared with old.
Litres.								*s. d.*	*d.*	
0·1	1	...	...	...	...	...	29·565	...	− 3½	7/10
1·0	10	1	...	...	...	...	11·947	− 2 4¾	− 1½	8/9
10·0	100	10	1	...	...	...	12·614	− 2 6¼	− 1½	7/8
100·0	1,000	100	10	1	...	22·888	...	+ 4 5½	+ 2¾	1 1/9
1,000·0	10,000	1,000	100	10	1	...	12·655	− 2 6¼	− 1½	7/8
Weight.	Quadruple Oz.	Double lb.	Tod.	Pack.	Ton.	At the temperature of maximum density.				
Metrical Equivalents.	Decilitre.	Litre.	Decalitre.	Hectolitre.	Kilolitre.					

Metrical Value.	Miscellaneous Values of old Names. For Wine and Beer Trades.	Difference from old measure, per cent. + Increase.	Difference from old measure, per cent. − Decrease.	Difference in value. In the £	Difference in value. In the Shilling.	Approximate Value of new Measure as compared with old.
Litres.				*s. d.*	*d.*	
200	Tierce = 200 new quarts ...	+4·818	...	+0 11½	+0½	31/40
250	Hogshead (Beer) = 250 ,, ,, ...	+1·907	..	+0 4½	+0½	31/40
300	,, (Wine) = 300 ,, ,, ...	+4·814	...	+0 11½	+0½	31/40
350	Puncheon (Beer) = 350 ,, ,, ...	+7·002	...	+1 4½	+0½	17/16
400	,, (Wine) = 400 ,, ,, ...	+4·818	...	+0 11½	+0½	31/40
600	Pipe = 600 ,, ,, ...	+4·849	...	+0 11½	+0½	31/40

NOTE.—To reduce to metrical units (litres) take the quart as unity; or to metres (new yards) cube take the tun as unity.

TABLE V.—PROPOSED NEW VALUES FOR OLD NAMES.

Measures of Capacity. New Corn and Fruit Measures.

Metrical Value.	Gill.	Quart.	Peck.	Sack.	Chaldron.	Difference from old measure per cent. + Increase.	Difference from old measure per cent. − Decrease.	Difference in Value. In the £	Difference in Value. In the Shilling.	Approx. value of new Measures compared with old.
Stere.								*s. d.*	*d.*	
·0001	1	...	...	...	...	...	29·565	...	− 3½	7/10
·001	10	1	...	...	...	...	11·947	− 2 4¾	− 1½	88/90
·01	100	10	1	...	...	10·049	...	+2 0	+1¼	11/10
·1	1,000	100	10	1	...	...	8·293	− 1 8	− 1	222/200
1·0	10,000	1,000	100	10	1	...	14·025	− 2 9½	− 1¾	444/400
Weight.	Quadruple oz.	Double lb.	Tod.	Double cwt.	Ton.	At the temperature of maximum density.				
Metrical Equivalents.	Dixmillistere.	Millistere.	Centistere.	Decistere.	Stere or Cube Metre.					

Metrical Value.	Miscellaneous Values of old Names. For Corn, Fruit, and Coke Trades.	Difference from old measure per cent. + Increase.	Difference from old measure per cent. − Decrease.	Difference in Value. In the £	Difference in Value. In the Shilling.	Approx. value of new Measures compared with old.
Stere.				*s. d.*	*d.*	
0·250 (¼ Hectolitres)	Quarter = 250 new quarts	...	− 14·025	2 9½	1¾	448/400
1·5 (1½ Kilolitres.)	Wey = 6 quarters = 1,500 new quarts ...	+3·164	...	7¾	¼	...
3·0 (3 Kilolitres.)	Last = 12 quarters = 3,000 new quarts ...	+3·136	...	7¾	¼	...

NOTE.—To reduce to metrical units (stere or centimetre) take the chaldron as unity.

1·1564 per cent. In square measure the French nomenclature is more complete, though less logical, than in its system of long measure, owing to the adoption of the name "are" for the square decametre, with a scale of one-tenth for multiples and sub-multiples instead of one-hundredth. This, unfortunately, the resources of our own nomenclature will not allow us to copy (*see* Table III.) without the interpolation of the three new names (left in blank), but our nomenclature in measures of capacity (*see* Tables IV., V., VI.) is more than equal to the occasion. The quart and the litre or cubic decimetre are fairly close in volume, the difference being under 12 per cent., or about one gill. The advocates of temperance would hardly be sorry that every consumer of a quart of liquor were mulct of a gill, though the price paid were the same. Nor would brewers, wine merchants, and publicans rebel. The difference of three-halfpence in the shilling, and half-a-crown in the pound would in any case not be difficult to calculate, and the reputed quarts and pints might very well continue as they are. Table No. IV. gives a series starting from the gill (= decilitre) up to the tun (= kilolitre), which, with the new metrical tierces, hogsheads, puncheons, and pipes, should amply suffice for the wine and beer trades, especially when supplemented by the four higher values given in Table VIa. for the intermediate measures. Tables No. V. and VIb. give the scale of measures for dry goods ranging from the gill (= dix-millistère) to the chaldron (= stère or cubic metre). The old saying by which "a pint is a pound all the world round" at last would become true; while the new gallon of water would still weigh 10 new lbs. or 5 kilogrammes, under the same conditions of temperature, purity, and density that it does at present.

The supreme advantage thus secured in the exact correlation of capacity and

TABLE VI.—PROPOSED NEW VALUES FOR OLD NAMES.

Intermediate Measures of Capacity.

(A.)

Metrical Value.	For Apothecaries.				For Wine and Beer Trade.				Difference from old measure per cent.		Difference in Value.		Approximate Value of new Measure as compared with old.
	Minim.	Fluid Carat.	Fluid Drachm.	Fluid Oz.	Pint.	Gallon.	Firkin.	But.	+ Increase.	− Decrease.	In the £	In the Shilling.	
Litre.											*s. d.*	*d.*	
·00005	1	...	...	...	...	...	...	...	...	32·341	...	...	$\frac{17}{32}$
·0005	10	1	...	...	...	...	..	...	...	...	...	...	...
·005	100	10	1	...	...	...	...	...	12·686	...	...	...	$\frac{2}{3}$
·05	1,000	100	10	1	...	...	...	...	40·869	...	...	...	$\frac{7}{8}$
·5	10,000	1,000	100	10	1	...	...	...	...	11·956	...	− 1½	$\frac{6}{5}$
5·0	100,000	10,000	1,000	100	10	1	...	...	10·068	...	+2 0	+1¼	$\frac{11}{10}$
50·0	1,000,000	100,000	10,000	1,000	100	10	1	...	22·288	...	+4 5½	+2¾	$\frac{13}{10}$
500·0	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	1·961	...	+0 4¾	+0¼	$\frac{21}{20}$
Weight.	One Grain.	Double Carat.	Drachm.	Double Oz.	Pound.	Stone.	Cwt.	Half Ton.	Distilled water at the temperature of maximum density and barometric pressure at sea-level in the latitude of London.				
Metrical Equivalent.	Half Dix-millilitre.	Half Milli-litre.	Half Centi-litre.	Half Deci-litre.	Half Litre.	Half Deca-litre.	Half Hecto-litre.	Half Kilo-litre.					

NOTE.—To reduce to metrical units (litres), take pint as unity and divide by two.

(B.) Cubic measure.

Metrical Value.	Cubic Hand.	Cubic Yard.
Cubic metres.		
0·001	1	...
1·000	1,000	1
Metrical Equivalent.	Decimetre Cube.	Metre Cube.

(C.)

Metrical Value.	For Cornchandlers, Greengrocers, Fruiterers, etc.					Difference from old measure per cent.		Difference in Value.		Approximate Value of new Measure as compared with old.
	Gill.	Pint.	Gallon.	Bushel.	Half Chaldron.	+ Increase.	− Decrease.	In the £	In the Shilling.	
Stere.								*s. d.*	*d.*	
·0005	5	1	...	...	...	...	11·956	...	− 1¼	$\frac{6}{5}$
·005	50	10	1	...	...	10·068	...	2 0	+1¼	$\frac{11}{10}$
·05	500	100	10	1	...	37·563	...	7 6	+4½	$\frac{22}{20}$
·5	5,000	1,000	100	10	1	...	14·025	−2 9½	− 1¼	$\frac{19}{20}$
Metrical Equivalent.	—	Half Milli-stere.	Half Hecti-stere.	Half Deci-stere.	Half Stere.	—	—	—	—	—

NOTE.—To reduce to metrical units (steres or cubic metres), take half-chaldron as unity and divide by two.

TABLE VII.—PROPOSED NEW VALUES FOR OLD NAMES.

Scale of Weights for usual Purposes.

Metrical Value.	Scruple.	Double Drachm.	Quadruple Oz.	Double Pound.	Quarter or Tod.	Pack or Double Cwt.	Ton or ½ Last.	Difference from Old Weight per cent. + Incr'se.	Difference from Old Weight per cent. − Decrease.	Approximate Value of New Weight compared with Old.
Gramme.										
1·0	1	...	...	...	...	...	...	...	22·068	$\frac{35}{37}$
10·0	10	1	...	...	...	...	...	28·601	...	$\frac{11}{12}$
100·0	100	10	1	...	...	...	...	...	11·815	$\frac{57}{64}$
1,000·0	1,000	100	10	1	...	...	...	10·232	...	$\frac{36}{37}$
10,000·0	10,000	1,000	100	10	1	...	...	...	21·260	$\frac{11}{12}$
									Ton Pack	Cwt. Pack
100,000·0	100,000	10,000	1,000	100	10	1	...	...	1·578 8·140	$\frac{11}{12}$ or $\frac{11}{12}$
								Last	Ton	Ton Last
1,000,000·0	1,000,000	100,000	10,000	1,000	100	10	1	0·949	1·578	$\frac{11}{12}$ or $\frac{132}{144}$
Metrical Equivalents.	Gramme.	Decagramme.	Hectogramme.	Kilogramme	Myriagramme	Hectokilogramme or Quintal.	Megagramme or Tonne.	—	—	—

NOTE.—To reduce to metrical units (grammes), take the scruple as unity; or to kilogrammes, take the double pound as unit.

For general use, coal, etc., the pack, or double cwt., being practically the sack of coal generally in use.

weight would more than compensate for any inconvenience incidental on the transition stage between the old and the new measures; and this will be readily apparent by inspecting the tables. The cubic inch and the cubic foot unavoidably drop out of the regular table for cubic measure, a new cubic inch being $\frac{1}{64}$ of a cubic decimetre or "hand," and $\frac{1}{64000}$ of a cubic metre or new yard. The metrical foot of 30 centimetres (= 12 new inches) for purposes of three dimensions, in like manner with purposes of two dimensions, unfortunately remains incommensurable at $\frac{37}{1000} = 37 \cdot 037$, and would have inevitably to drop out of use. Tables VII., VIII. and IX. give the proposed new decimal scales of weights for various purposes based on the unit gramme, with the old names preserved. Our present pound avoirdupois is 10·2317 per cent. smaller than half a kilogramme, but the two-mark weight (pound) in use in France before the Revolution was lighter than the half-kilo by about the same amount, yet the name pound (livre) is still in current everyday use for the latter weight, the change in magnitude not having occasioned any sensible inconvenience, as both corresponded to an everyday want. The new pound would evidently do the same, and the difference in monetary value, $1\frac{1}{4}d.$ in the shilling, and 2*s.* in the pound would be quite as easy to adjust as 10 centimes in the franc. The other important unit of weight, the ton, would, on the contrary, be diminished. but the variation would be only just over $1\frac{1}{2}$ per cent., or $\frac{1}{4}d.$ less in the shilling, and 4*d.* less in the pound. The tables are otherwise sufficiently explanatory of the suggested alterations in names and values, bringing the British measures in line with the metrical system. Tables X., XI., XII. and XIII. of metrical measures are appended to show the vast area which the French system covers.

On the whole, in the proposed new values for old names, which we are suggesting as a promising method for smoothing over a very practical disability under which we are labouring in our foreign trade, the two laws which comparative metrology reveals as governing the transmission of weights and measures through the ages have been fairly closely observed.

The new weights have generally suffered a diminution while the lengths have suffered

TABLE VIII.—PROPOSED NEW VALUES OF OLD NAMES.

Intermediate Scale of Weights No. 1.

Metrical Value.	Mite.	Grain (Troy).	Double Carat.	Drachm (Troy).	Double Ounce (avp.).	lb. (avp.).	Stone.	Cwt.	Half Ton.	Difference from Old Weight per cent. + Increase.	Difference from Old Weight per cent. − Decrease.	Approximate Value of New Weight compared with Old.
Gramme.												
0·005	1	...	...	...	...	...	...	...	...	54·796	...	1/2
0·05	10	1	...	...	...	...	...	...	...	...	22·835	1/4
0·5	100	10	1	...	...	...	...	...	...	...	3·548	1/4
5·0	1,000	100	10	1	...	...	...	...	...	28·601	...	1/4
50·0	10,000	1,000	100	10	1	...	...	...	...	...	11·815	1/8
500·0	100,000	10,000	1,000	100	10	1	...	...	...	10·232	...	1/8
5,000·0	1,000,000	100,000	10,000	1,000	100	10	1	...	...	...	25·234	1
50,000·0	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	...	...	1·578	1/2
500,000·0	100,000,000	10,000,000	1,000,000	100,000	10,000	1,000	100	10	1	57·473	...	1/8
Metrical Equivalents.	Half Centi-gramme.	Half Deci-gramme.	Half Gramme.	Half Deca-gramme.	Half Hecto-gramme.	Half Kilo-gramme.	Half Myria-gramme.	Half Hecto-kilo-gramme.	Half Mega-gramme.	—	—	—

NOTE.—To reduce to metrical units (grammes), take the drachm as unity and multiply by 5, or shift the decimal point one space to the right and divide by 2.

For use by Apothecaries, Grocers, Greengrocers, Butchers, etc.

an augmentation in value. With reference to the latter, it is curious to remark that through Easterling (Belgian) sources we derived from the Tungri a sequence of lineal measures with a mile of 6,610 feet = 10 furlongs = 100 chains = 1,000 fathoms, very closely equal to the double metrical units proposed in Table II. The Tungrian or Drusan foot = $1\frac{1}{20}$ Roman foot = 1·1016 standard British foot, with the corresponding "yard and a handfull" or 40-in. ell = 3·305 ft. (= very nearly 1 metre, within $2\frac{1}{2}$ per cent. in excess), came to us at the same time. These measures held their own against those founded on the 12-in. foot, which were introduced in A.D. 950, and, indeed, so successfully that they had to be suppressed by statute in 1430. To this extent the adoption of the new values for old names would constitute a curious reversion to a very ancient system of British measures.

The enlightened policy which has been inaugurated by the Australian Commonwealth in the adoption of metrical units might well encourage those nearer home to follow suit. Peradventure the retention of the names which sound familiar to our ears might make this adoption we are all resigned to, if not actually desire, all the easier.

TABLE IX.—PROPOSED NEW VALUES FOR OLD NAMES.

Intermediate Scale of Weights No. 2.

Metrical Values.	For Jewellers, Dealers in Precious Stones, etc.						Difference from Old Weight per cent.		Approximate Values of New Weights as compared with old.
	Five mites.	Carat.	Penny-weight.	Ounce.	Half Pound.	Clove or Half Stone.	+ Increase.	− Decrease.	
Grammes.									
0·025	1	...	...	...	...	...	54·796	...	$\frac{25}{16}$
0·25	10	1	...	...	...	...	...	22·835	$\frac{25}{32}$
2·5	100	10	1	...	...	...	60·771	...	$1\frac{03}{64}$
25·0	1,000	100	10	1	...	...	...	11·815	$\frac{07}{64}$
250·0	10,000	1,000	100	10	1	...	10·231	...	$\frac{25}{32}$
2,500·0	100,000	10,000	1,000	100	10	1	...	Stone. 25·234 Clove. 21·263	Stone. $\frac{3}{4}$ Clove. $\frac{25}{32}$
Metrical Equivalents.	Quarter Deci-gramme.	Quarter Gramme.	Quarter Deca-gramme.	Quarter Hecto-gramme.	Quarter Kilo-gramme.	Quarter Myria-gramme.	—	—	—

NOTE.—To reduce to metrical units (grammes), take the pennyweight as unit and multiply by 2·5, or shift the decimal point one space to the right and divide by 4.

TABLE X.—METRICAL LONG MEASURE.

Names.	Abbreviations.	Values.	Intermediate Values or Units.	Remarks.
Micrometre ...	mcm.	0·000001 (10^{-6})		The range in practice is from a millimetre to a kilometre, *i.e.* from $\frac{1}{1000}$ of an inch to $\frac{1}{4}$ of a mile, but the ground is covered theoretically from $\frac{1}{25400}$ of an inch to a unit = 621·38 miles, not very far off $\frac{1}{10}$ of the earth's equatorial circumference—a most surprising result to achieve with a single unit and its divisors and multiples.
Centimillimetre ...	cmm.	0·00001 (10^{-5})		
Dixmillimetre ..	xmm.	0·0001 (10^{-4})		
Millimetre... ...	mm.	0·001 (10^{-3})		
Centimetre ...	cm.	0·01 (10^{-2})		
Decimetre	dm.	0·1 (10^{-1})	Double decimetre = 0·2m. (for office use)	
Metre	m.	1·0 (10^{0})	...	
Decametre ...	ðm.	10·0 (10^{1})	Double decametre = 20·0m. (for surveying)	
Hectometre ..	hm.	100·0 (10^{2})		
Kilometre	km.	1,000·0 (10^{3})		
Myriametre ..	μrm.	10,000·0 (10^{4})		
Hectokilometre ...	hkm.	100,000·0 (10^{5})		
Megametre ..	μym.	1,000,000·0 (10^{6})		

TABLE XII.—METRICAL CUBE MEASURE.

Names.	Abbreviations and Symbols.	Numerical Values.	First Intermediate Values. For Dry Measures.	Abbreviations and Symbols.	Second Intermediate Values. For Liquid Measures.	Abbreviations and Symbols.	Remarks.
Cubic Micrometre	mcm.^{3}	$(10^{-6})^3 = 0{\cdot}000,000,000,000,000,001$ $(10^{-5\ 2/3})^3 = 0{\cdot}000,000,000,000,000,01$ $(10^{-5\ 1/3})^3 = 0{\cdot}000.000,000,000,000,1$					The range of measurement where the units progress by the cube of 10 is unavoidably enormous. Thus the cubic micrometre is small enough to be compared to the volume of a colony of bacteria; and the number of molecules of hydrogen contained in it could be expressed by a comparatively low exponential value of 10. While the cubic megametre is a volume comparable to that of the globe itself, being no less than $\frac{1}{1000}$th of that volume, or equal to 239,925,772 cubic miles.
,, Centimillemetre	cmm.^{3}	$(10^{-5})^3 = 0{\cdot}000,000,000,000,001$ $(10^{-4\ 2/3})^3 = 0{\cdot}000,000,000,000,01$ $(10^{-4\ 1/3})^3 = 0{\cdot}000,000,000,000,1$					
,, Dixmillimetre	xmm.^{3}	$(10^{-4})^3 = 0{\cdot}000,000,000,001$ $(10^{-3\ 2/3})^3 = 0{\cdot}000,000,000,01$ $(10^{-3\ 1/3})^3 = 0{\cdot}000,000,000,1$					
,, Millimetre	mm.^{3}	$(10^{-3})^3 = 0{\cdot}000,000,001$ ... ... $(10^{-2\ 2/3})^3 = 0{\cdot}000,000,01$ ... ... $(10^{-2\ 1/3})^3 = 0{\cdot}000,000,1$			Microlitre Centimillilitre Dixmillilitre	mcl. cml. xml.	
,, Centimetre	cm.^{3}	$(10^{-2})^3 = 0{\cdot}000,001$ ... ... $(10^{-1\ 2/3})^3 = 0{\cdot}000,01$ ... ... $(10^{-1\ 1/3})^3 = 0{\cdot}000,1$	Microstere Centimillistere Dixmillistere	mcs. cms. xms.	Millilitre Centilitre Decilitre	ml. cl. dl.	
,, Decimetre	dm.^{3}	$(10^{-1})^3 = 0{\cdot}001$ ... ... $(10^{-0\ 2/3})^3 = 0{\cdot}01$ ... ... $(10^{-0\ 1/3})^3 = 0{\cdot}1$	Millistere Centistere Decistere	ms. cs. ds.	Litre Decalitre Hectolitre	l. dl. $\frac{h}{}$l. (hl.)	
,, Metre	m.^{3}	$(10^{0})^3 =$ ... ... 1·0 $(10^{0\ 2/3})^3 =$ ... ... 10·0 $(10^{0\ 1/3})^3 =$ ... ... 100·0	Stere Decastere Hectostere	s. ds. $\frac{h}{}$s. (hs.)	Kilolitre Myrialitre Hectokilolitre	κl. (kl.) μl. $\frac{h}{}\kappa$l. (hkl.)	
,, Decametre	dm.^{3}	$(10^{1})^3 =$ ... ... 1,000·0 $(10^{1\ 1/3})^3 =$ ... ... 10,000·0 $(10^{1\ 2/3})^3 =$ ... ... 100,000·0	Kilostere Myriastere Hectokilostere	κs. (ks.) μs. $\frac{h}{}\kappa$s.(hks.)	Megalitre	$\mu\gamma$l.	
,, Hectometre	$\frac{h}{}$m.^{3} (hm.^{3})	$(10^{2})^3 =$ .. ... 1,000,000·0 $(10^{2\ 1/3})^3 =$ ... ... 10,000,000·0 $(10^{2\ 2/3})^3 =$ ... 100,000,000·0	Megastere	$\mu\gamma$s.			
,, Kilometre	κm.^{3} (km.^{3})	$(10^{3})^3 =$ ... 1,000,000,000·0 $(10^{3\ 1/3})^3 =$ ... 10,000,000,000·0 $(10^{3\ 2/3})^3 =$ ... 100,000,000,000·0					
,, Myriametre	μm.^{3}	$(10^{4})^3 =$ 1,000,000,000,000·0 $(10^{4\ 1/3})^3 =$ 10,000,000,000,000·0 $(10^{4\ 2/3})^3 =$ 100,000,000,000,000·0					
,, Hectokilometre	$\frac{h}{}\kappa$m.^{3} (hkm.^{3})	$(10^{5})^3 =$ 1,000,000,000,000,000·0 $(10^{5\ 1/3})^3 =$ 10,000,000,000,000,000·0 $(10^{5\ 2/3})^3 =$ 100,000,000,000,000,000·0					
,, Megametre	$\mu\gamma$m.^{3}	$(10^{6})^3 = 1,000,000,000,000,000,000{\cdot}0$					

TABLE XI.—METRICAL SQUARE MEASURE.

Names.	Abbreviations and Symbols.	Numerical Values.	Intermediate Values. Names.	Abbreviations and Symbols.	Remarks.
Sq. micrometre	mcm.²	$(10^{-6})^2 = 0{\cdot}000,000,000,001$			The value of a square micrometre is the inconceivably small area = 155×10^{-9} sq. in ; on the other hand, a square megametre is no less than 316,118 sq. miles, about the $\frac{1}{76}$th part of the surface of the globe.
Sq. Centimillimetre	cmm.²	$(10^{-5})^2 = 0{\cdot}000,000,000,1$			
Sq. dixmillimetre	xmm.²	$(10^{-4})^2 = 0{\cdot}000,000,01$			
Sq. millimetre	mm²	$(10^{-3})^2 = 0{\cdot}000,001$			
Sq. centimetre	cm.²	$(10^{-2})^2 = 0{\cdot}000,1$	Micrare	mca.	
Sq. decimetre	dm.²	$(10^{-1})^2 = 0{\cdot}01$	Centimilliare	cma.	
Sq. metre	m.²	$(10^{0})^2 = 1{\cdot}0$	Dixmilliare	xa.	
Sq. decametre	ðm.²	$(10^{1})^2 = 100{\cdot}0$	Milliare	ma.	
Sq. hectometre	ήm.² (hm.²)	$(10^{2})^2 = 10,000{\cdot}0$	Centiare	ca.	The intermediate values given by the divisions and multiples of the "are" progress by 10 and not by 100, as in the previous case, and are therefore well fitted to express the sequence of surfaces for all ordinary purposes of measurement in the arts and sciences. The range is from the micrare = sq. centimetre = 0·155 of a sq. in. to the megare of 38·61 sq. miles.
Sq. kilometre	κm.² (km.²)	$(10^{3})^2 = 1,000,000{\cdot}0$	Deciare	da.	
Sq. myriametre	μm.²	$(10^{4})^2 = 100,000,000{\cdot}0$	Are	a.	
Sq. hectokilometre	ήκm². (hkm.²)	$(10^{5})^2 = 10,000,000,000{\cdot}0$	Decare	ða.	
Sq. megametre	μγm²	$(10^{6})^2 = 1,000,000,000,000{\cdot}0$	Hectare	ήa (ha.)	
			Kilare	κa (ka.)	
			Myriare	μa.	
			Hectokilare	ήκa (hka.)	
			Megare	μγa.	

TABLE XIII.—METRICAL WEIGHT.

Names.	Abbreviations and Symbols.	Numerical Value.	Intermediate Values Names.	Abbreviations.	Remarks.
Microgramme	mcg.	$0{\cdot}000,001\ (10^{-6})$	...	...	The gramme is the weight of a cubic millimetre of water at maximum density and average pressure, and is 15·43235 grains of the British standard. The range is from 154×10^{-7} of a grain up to ·98421 of a British ton.
Centimilligramme	cmg.	$0{\cdot}000,01\ (10^{-5})$	...	...	
Dixmilligramme	xmg.	$0{\cdot}000,1\ (10^{-4})$	...	...	
Milligramme	mg.	$0{\cdot}001\ (10^{-3})$	...	...	
Centigramme	cg.	$0{\cdot}01\ (10^{-2})$	...	...	
Decigramme	dg.	$0{\cdot}1\ (10^{-1})$	...	...	
Gramme	g.	$1{\cdot}0\ (10^{0})$	Microtonne	...	The choice of the gramme as unit name was apparently as unfortunate as to absolute size as the watt; both would have been better a thousand times larger. The survival of the livre and its divisions, and the addition of the extraneous names of quintal and tonne in common practice amply prove this to be the case.
Decagramme	ðg.	$10{\cdot}0\ (10^{1})$	...	...	
Hectogramme	ήg. (hg.)	$100{\cdot}0\ (10^{2})$	¼ livre =	½kg = 125gr.	
			½ livre =	¼kg. = 250gr.	
			¾ livre =	¾kg. = 375gr.	
Kilogramme	κg. (kg.)	$1,000\ (10^{3})$	1 livre =	½kg. = 500gr.	
Myriagramme	μg.	$10,000\ (10^{4})$	...	...	
Hectokilogramme	ήκg (hkg.)	$100,000\ (10^{5})$ =	Quintal (q.)	...	
Megagramme	μγg.	$1,000,000\ (10^{6})$ =	Tonne (t.)	...	

Henry L Pollew

Machinery in the Tea Industry.

By H. J. KERSTING GREEN.

(Continued from page 431, vol. 6.)

THE object in rolling is to twist the leaves, and in the course of this process to bruise the outer covering of the cells contained in the leaf, and expose the contents to the atmosphere and set up a form of fermentation. When accomplishing this by hand, a certain quantity of the leaf was placed on a table covered with a bamboo or rattan mat, the leaves propelled across the table under pressure of the two hands, the diagram of the motion being V-shaped. Another method was to put a quantity of leaf into a canvas bag twisted firmly into a round shape, which was thrown on to the floor, when a man, holding fast by a bamboo horizontal bar, rolled and twisted the ball by the perpetual motion of his feet, while the weight of his body compressed it into a small size. This latter system is one described in some notes on tea from China, and was adopted in making what was known as caper tea. There are copies of prints showing the rolling by foot power in India, but the process was not generally adopted.

In the earlier rolling machines, a motion akin to either of the above, was naturally aimed at. Mr. J. C. Kinmond, of the Assam Tea Co., produced the first machine put into operation in 1866, and during that year, Messrs. Burgess and Campbell filed their specification for a machine for "treating and curing leaf" (Fig. 20).

The leaf being fed along the trough *E*, was carried by the drum *A* and pressed against the surface of a flexible material *B B*, held in a fixed position by the weight *C*. Unfortunately, the procedure for filing specifications in India does not admit of copies being sent home or any information

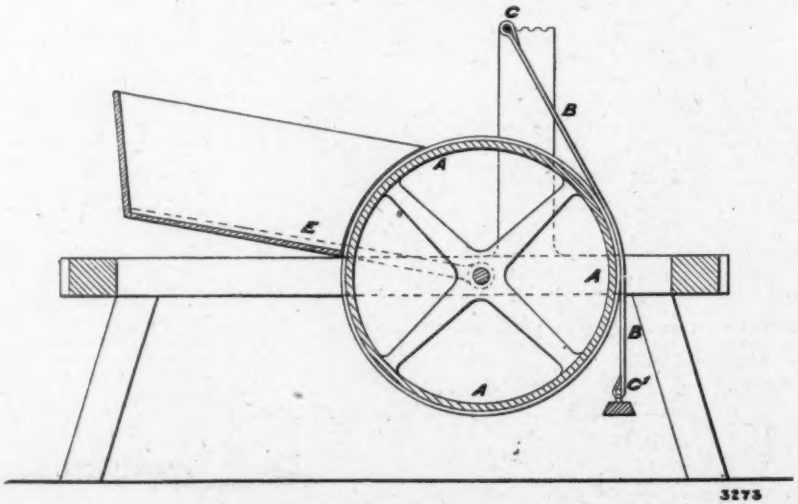


FIG. 20.—BURGESS AND CAMPBELL'S ROLLER.

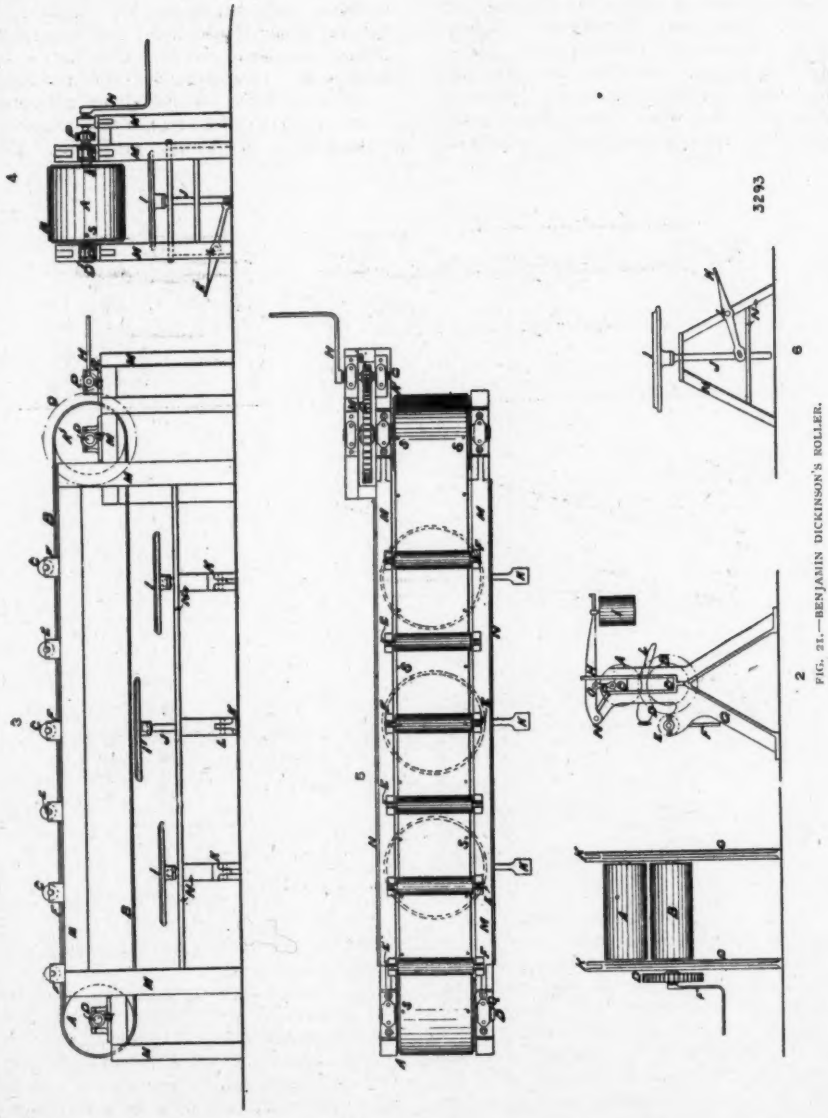


FIG. 21.—BENJAMIN DICKINSON'S ROLLER.

beyond just the subject matter; the writer can, however, remember easily a dozen applications in the Calcutta office almost identical with the immediately foregoing.

Mr. Benjamin Dickinson's improvements in treating the leaves of the tea-plant may be briefly described as follows: the freshly gathered leaves that have been withered, but which yet contain in their cells the natural juices were placed in a bag of hair or some other strong and porous material, the bag being nearly filled with leaf. These bags of leaf were then placed between rollers and pressed, the requisite twist being imparted to the leaves by the endless bands passing over the revolving tables as shown at *III* in Fig. 21, or two endless bands, as in Fig. 22, set at an angle and running at different speeds. The description does not very clearly state whether the leaf remained in the bag during the whole process; or whether, after the bruising had been effected, it was taken out for rolling and twisting either by the hand and revolving tables, or between the two hands as mentioned. Theoretically, this machine in its various forms had much to recommend it, but the amount of attention it required to keep the leaf in the machine at all, would be equivalent to performing the operation by hand.

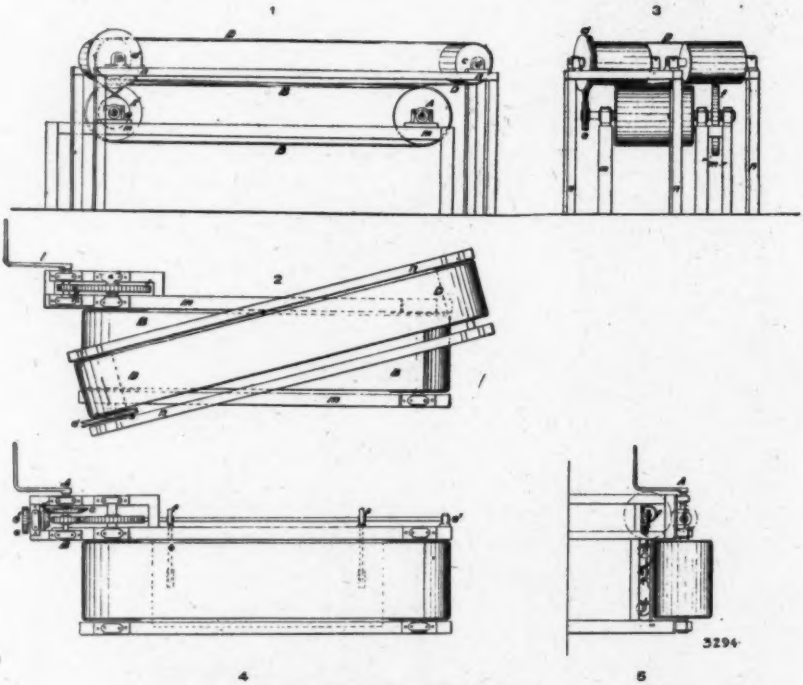


FIG. 22.—BENJAMIN DICKINSON'S ROLLER.

In 1871 a bag process rolling machine was introduced by William Haworth, and further improved in 1875 (Figs. 23-24).

The patentee's claim is explicit and clear—the arranging of two or three rollers, with even or uneven surfaces, and revolving all in the same direction, to act on a bag of tea-leaf placed between them: the

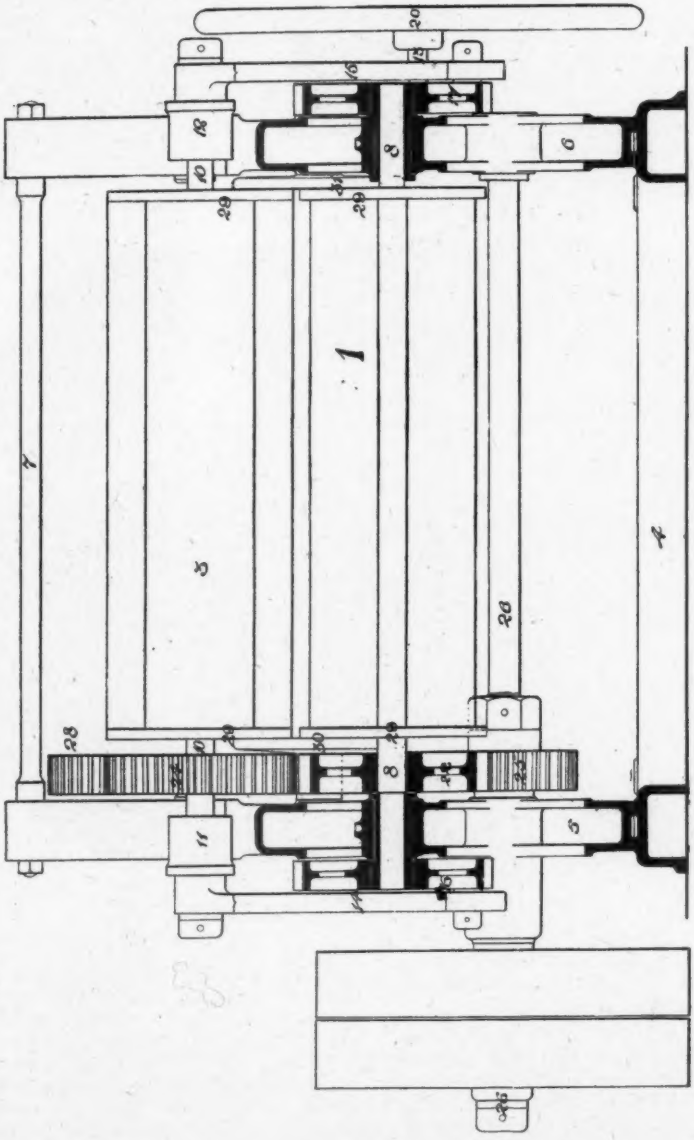


FIG. 23.—WILLIAM HAWORTH'S ROLLER.

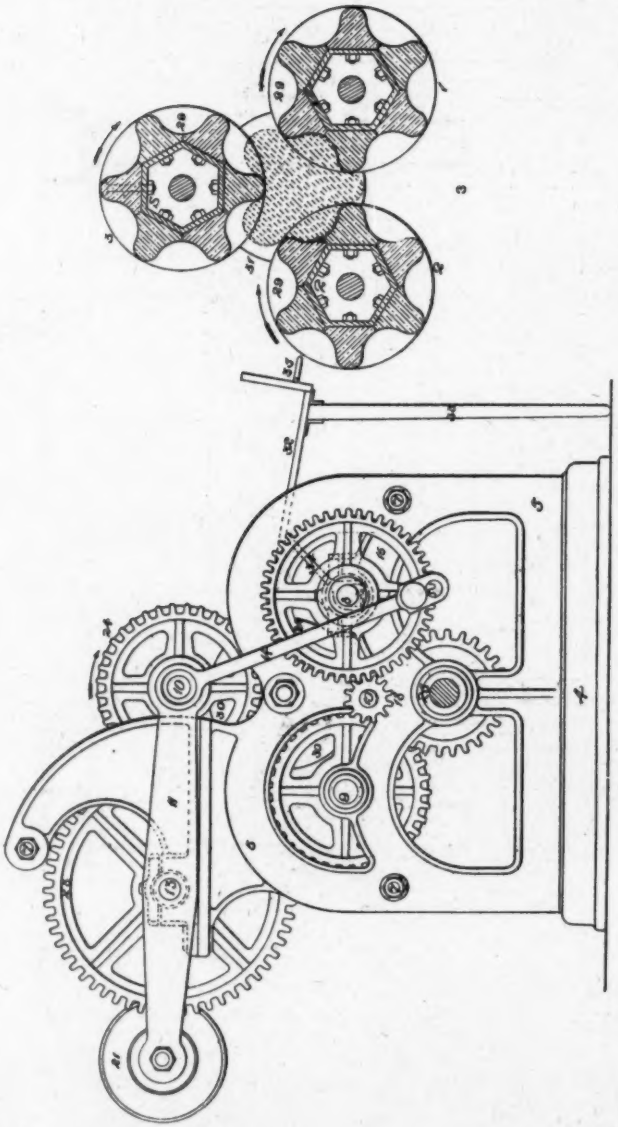


FIG. 24.—WILLIAM HAWORTH'S ROLLER.

arranging of one of the rollers of a tea-leaf rolling machine to be movable towards or from the other roller or rollers without disengagement from the driving gear: the making of the bag for the tea-leaf of vulcanised rubber, or leather alone, or combined with canvas or other woven material. The position of the bag and the rollers is clearly shown in Fig. 24. cross-section.

The great drawbacks to this machine were filling the bags, and their tendency to jump out of the rollers, also the great difficulty in keeping them sweet; otherwise, as a roller, it was a success, and became a standard type.

In the meantime Mr. William Jackson brought out his single-action rolling machine (Fig. 25), which was practically the turning-point in tea machinery generally. The rolling-box, or cap, was hung by four suspension rods attached to a frame by ball-and-socket bearings; there were two cranks, the one making half as many turns as the other. The motion, therefore, imparted to the rolling-box would be either V shaped or ∞. The V was generally considered the better motion. In order to retain the leaf under the cap or rolling-box it was surrounded by a wooden frame or jacket, which was free to move up and down, the lower table being hinged at the front or driving side of the machine, pressure being applied to the leaf by means of the weights and chains running over grooved pulleys. For filling the machine with leaf, the bottom table was pressed down and secured to the cross-bar at the back. When the quantity of leaf to be rolled had been placed inside the jacket, the fastening was released and the weights brought the table into position again,

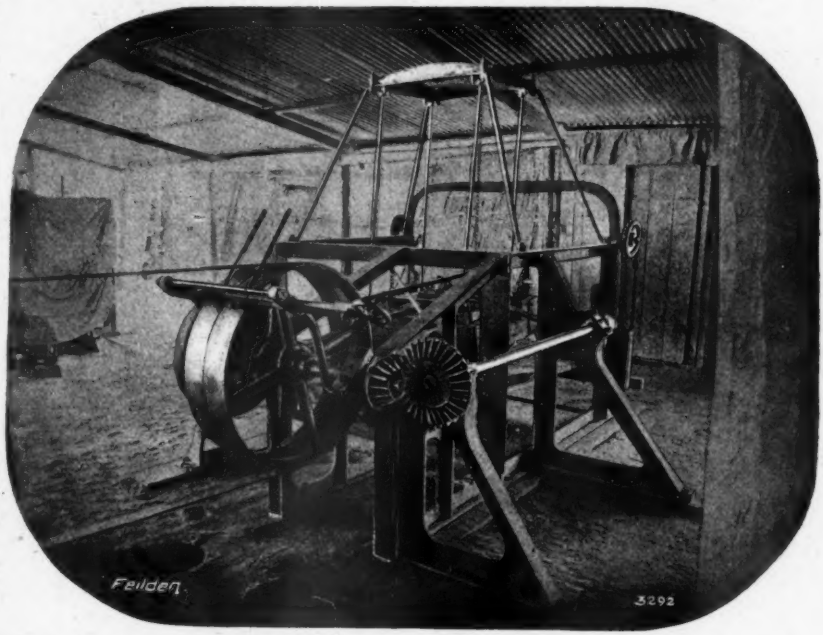


FIG. 25.—WILLIAM JACKSON'S SINGLE-ACTION ROLLER.

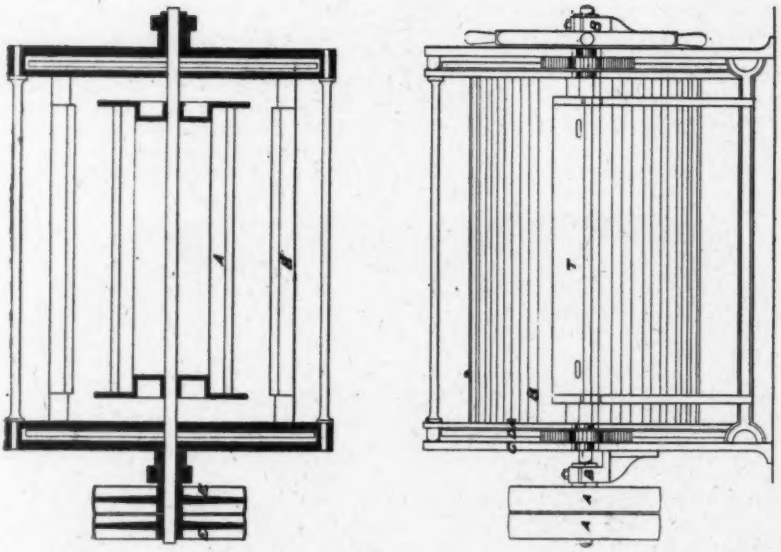
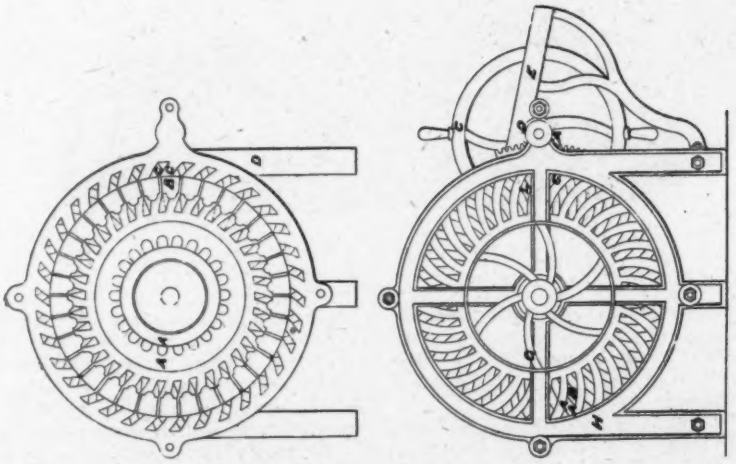


FIG. 26.—LYLE'S ROLLER.



more weights being added to increase the pressure. The centre portion of the table was hollowed out, and formed a well, and was fitted with ribs, the top rolling-box being also concaved and ribbed. Subsequent improvements were introduced, the hinges of the table dispensed with, and arranged to move up and down parallel with the frame, a filling hood applied to the top rolling-box, and a discharging door to the well in the table.

The capacity of the machine is small, only about 100 lbs. at a fill, and has therefore given place to larger types, but with moderately fine leaf, it is a most excellent roller.

A further development of the bag machine is embodied in Lyle's "Improvements in Machinery for Rolling Leaf Tea," 1875 (Fig. 26):—

The bags of leaf are passed round a revolving barrel, which revolves inside a cylindrical frame and mounted on a shaft. The cylindrical frame in which this barrel revolves has for its periphery a series of bars which fit into slots in the frame ends, so as to be capable of being moved either towards or away from the internal barrel. The space between the two barrels in which are the bags of leaf is decreased as the rolling progresses, and pressure is required. The advantage of this over other bag machines will be at once apparent. About this time attention, both in India and at home, was in the direction of other and simpler means for rolling, and the year following saw Mr. William Jackson's single-action roller vastly improved, which is best described as a quadrilateral, angular, ovular, self- or hand-feeding and discharging tea-leaf rolling machine. Two rolling plates move directly across each other, each guided in a parallel line and moving at comparatively different speeds to each other (Fig. 27).

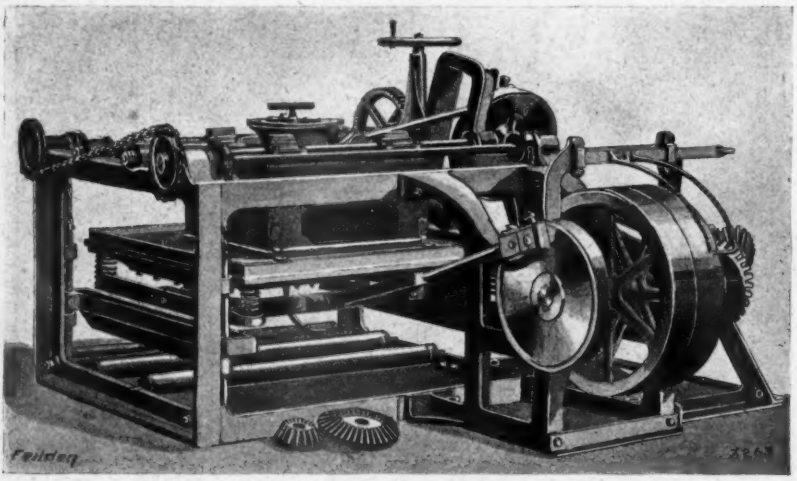


FIG. 27.—JACKSON'S "STANDARD" CROSS-ACTION ROLLING MACHINE.

The table or bottom plate or surface is connected to the disc on the driving shaft, and moves in that direction; the top surface or rolling box to a disc, as in the single-action machine, the diagram of the motion produced therefore being ○.

The capacity of the machine was increased to double that of the single machine. The writer can mention numerous instances where the Standard Cross-Action

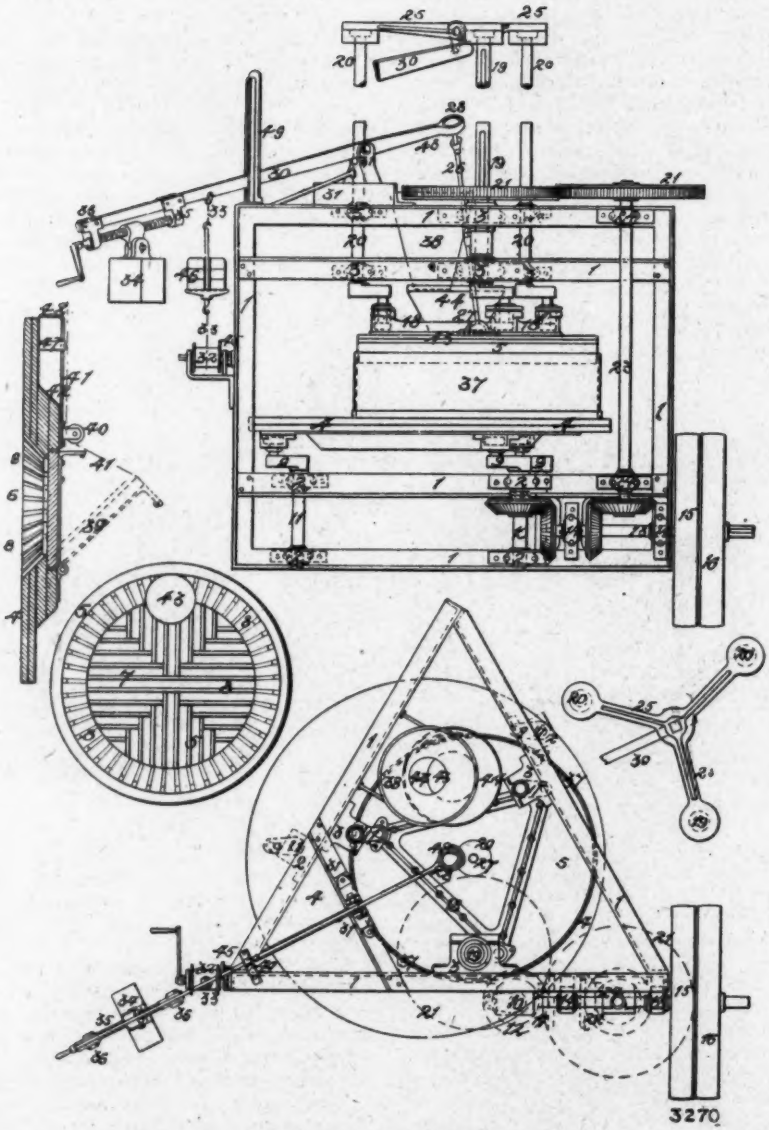


FIG. 28.—J. C. KINMOND'S TRIANGULAR-FRAMED DOUBLE-ACTION ROLLER.

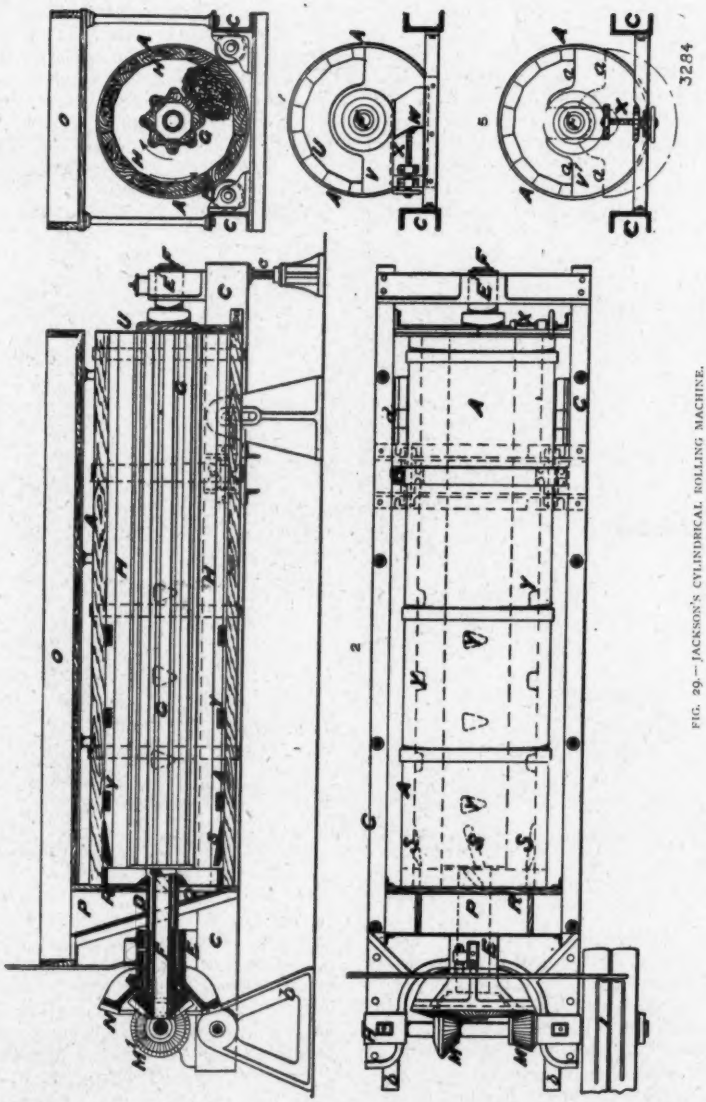


FIG. 29.—JACKSON'S CYLINDRICAL ROLLING MACHINE.

Tea-Roller can be seen doing excellent work, as it is still a favourite, in spite of the many subsequent inventions and improvements.

The same year, 1876, J. C. Kinmond brought out his triangular-framed double-action tea-roller (Fig. 28), in which the action was imparted by means of cranks, the gearing being circular. The bottom surface remains at the same height, while the top rolling-box is free to move up and down in the jacket, and the pressure adjusted by the lever and weights. With fine and well-withered leaf this machine gives the most gratifying results.

A departure from the track was made by Mr. Jackson in his patent of 1879. It consisted of a barrel or cylinder, with a grooved, polygonal, fluted, or other uneven internal surface composed of wood, revolving in one direction, and a fluted roller in the centre running the entire length of the barrel revolving in the opposite direction, the leaf being fed into the barrel at the driving end, and discharged at the opposite. By raising or lowering the discharge end of the machine, the passage of the leaf and the duration of the rolling process could be increased or retarded as circumstances demanded. If so desired, the action could be one of continuous feed and discharge, while the adjustment of pressure is regulated by the quantity of leaf fed into the barrel (Fig. 29).

Early in 1880 Mr. A. C. G. Thompson brought out a machine possessing some novel features, somewhat wide, in their application. The appliance, it was claimed, held improvements for, among others, husking and polishing rice and rolling tea-leaves. The constituents of these two commodities hardly, however, lend themselves to the alternate treatment in the one machine; the device, therefore, appears to have been relegated to husking purposes only.

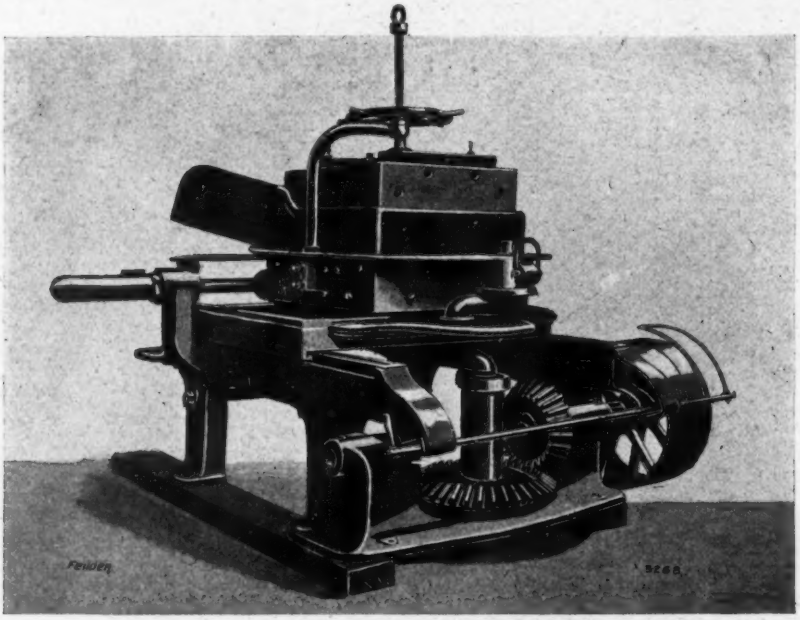


FIG. 30.—JACKSON'S "EXCELSIOR" TEA ROLLING MACHINE.

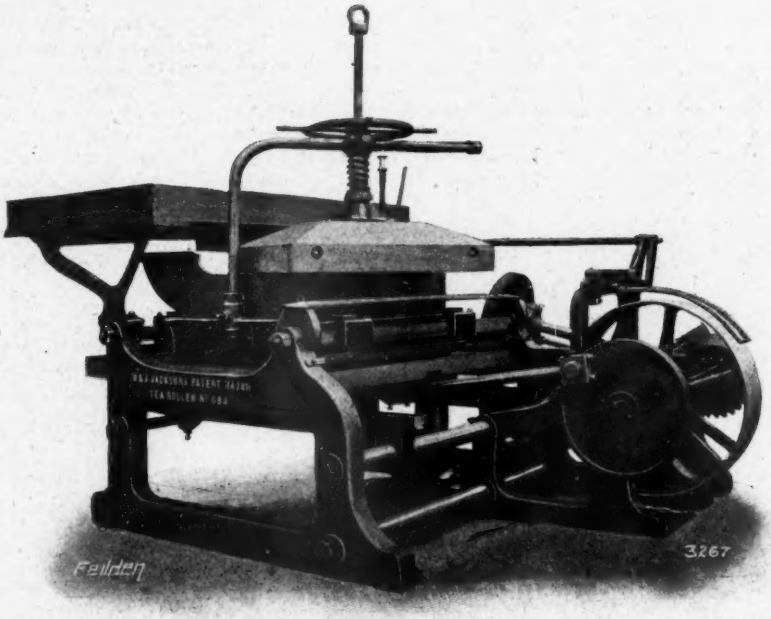


FIG. 31.—JACKSON'S "RAJAH" TEA ROLLING MACHINE.

In the same year Mr. William Jackson produced his Excelsior Roller (Fig. 30). A most ingenious contrivance was embodied in the driving arrangements, the cross-action motion to the upper and lower rolling surfaces being secured by means of a double-crank shaft running perpendicularly in a socket bearing of a horizontal bevel wheel, rotating on a vertical stud, the socket bearing for the crank-shaft being placed midway between the centre of the bevel wheel and the periphery.

An advantage possessed by the Excelsior over previous rollers was in imparting the motion to the jacket instead of the top rolling-box or cap. The horizontal sleeve bearings at the back, and the collar bearing on the crank at the front of the machine kept the jacket, if only the distance of the thickness of a piece of paper, free from the bottom table. The top rolling-box being comparatively free inside the jacket, this improvement possessed some striking advantages. In the early stages of rolling, before the leaf begins to take a twist, it is inclined to be rebellious, and over which a loose jacket has practically no control, the partial freedom of the cap yielded to the leaf, with the result that it was not thrown out as before.

Next, the top box could be swung out of the jacket by means of the davit for cleaning purposes, while the jacket could be lifted up and tilted back, the horizontal sleeve-bearings forming the hinge, thus allowing the bottom table to be scoured with ease.

Jas. Peter Brougham's roller, patented in 1881, was a large hollow cylinder, with a shifting, rotating roller mounted within it for treating—or agitating, rubbing, pressing, and rolling—the leaves. Opinion had, however, by this time been pretty well established in favour of two rolling surfaces on a horizontal plane, although J. C. Kinmond's centrifugal roller consisted of two revolving surfaces, vertically connected by a drum, a sort of mid-way

alternative, and gave very satisfactory results.

The introduction of the Excelsior roller, however, may be said to have been the beginning of a new era in rolling as part of the manufacturing process of tea. The single and cross-action machines had practically established the most suitable means for rolling, and attention was attracted to the possibility of the requirements for something more than merely pressing the juice out of the leaf; and the rolling process was split up into two, three, and even four distinct operations, the number and length of these forming the subject of frequent and heated discussions. Clocks and sand-glasses found their way into the hands of the rolling machine attendants. On the Excelsior back spindle shield, opposite the driving pulley, was fixed a rather ingenious little time-recorder driven by a gut band from the main driving spindle.

Mr. Jackson next produced his Rajah roller (Fig. 31), a combination of the cross-action and Excelsior; the motion could be arranged either O or OOO by gear wheels dependent upon the relative number of teeth in the driven and driving wheels.

The bottom rolling-table ran in fixed guides, the top rolling-box loose as in the Excelsior machine and the jacket guided on square bars as used in the Cross Action machine for the rolling box. The cross-action of the two tables was attained by cranks as in the Cross Action machine—pressure arrangements for the cap being as in the Excelsior.

According to their 1885 specification, Messrs. Kinmond and Richardson's roller (Fig. 32) consisted of a circular hopper lined with wood, opening at one side; within the hopper, the upper table (rolling box) is free to move vertically, and can be raised by a screw, the hopper and the table receiving their motion from a crank. The

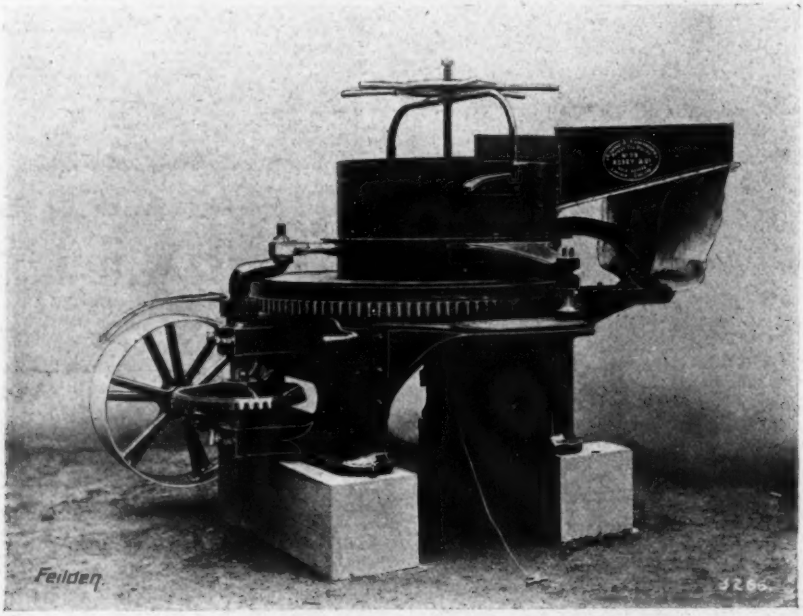


FIG. 32—KINMOND AND RICHARDSON'S TEA ROLLING MACHINE.

under table is caused to revolve upon its axis in a contrary direction to the upper table by an eccentric on the vertical shaft and ratchet gear.

Opinions are divided as to the success of this machine. The increased depth of the hopper or jacket added considerably to the capacity, but the reverse motion of the rolling surfaces was perhaps a doubtful advantage.

For some unexplained reason, an idea existed throughout the tea districts that any material other than wood (and teak preferably) coming in contact with the leaf in the course of rolling was deleterious. About the period 1886-87, rolling machines began to get something to do, and the surface of the bottom table especially was found to give out long before the season was over. A more lasting material was sought for, and granite was selected as being the most suitable—in some instances granite being used for the top rolling cap and marble for the bottom table. Either arrangement proved an advantage over the wood from an economical point of view, while, as far as could be judged, the teas did not suffer.

Information is not at hand whether Mr. Jackson protected this improvement, but an infringement or evasion of right was effected with some success by the author,

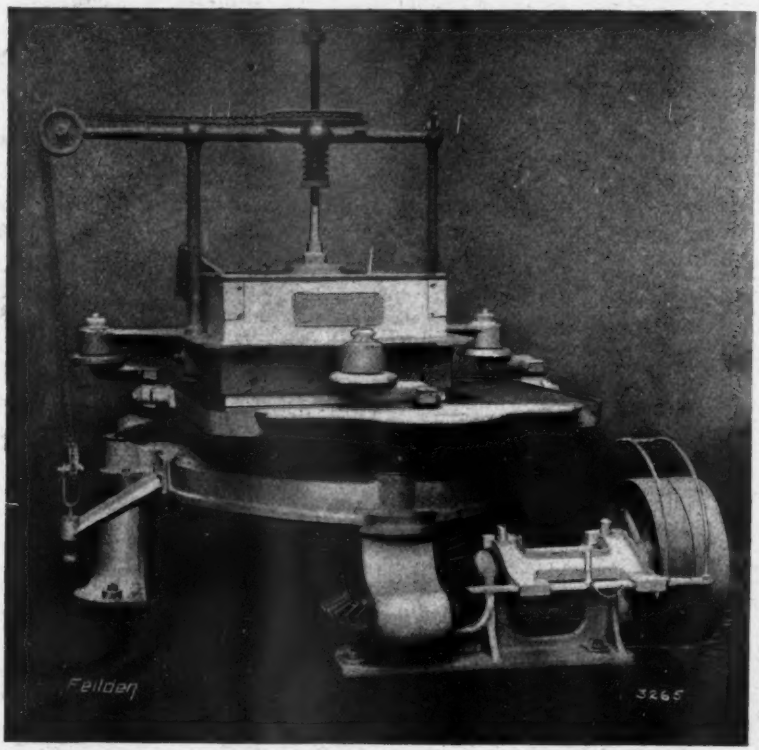


FIG. 33.—JACKSON'S "RAPID" ROLLER.

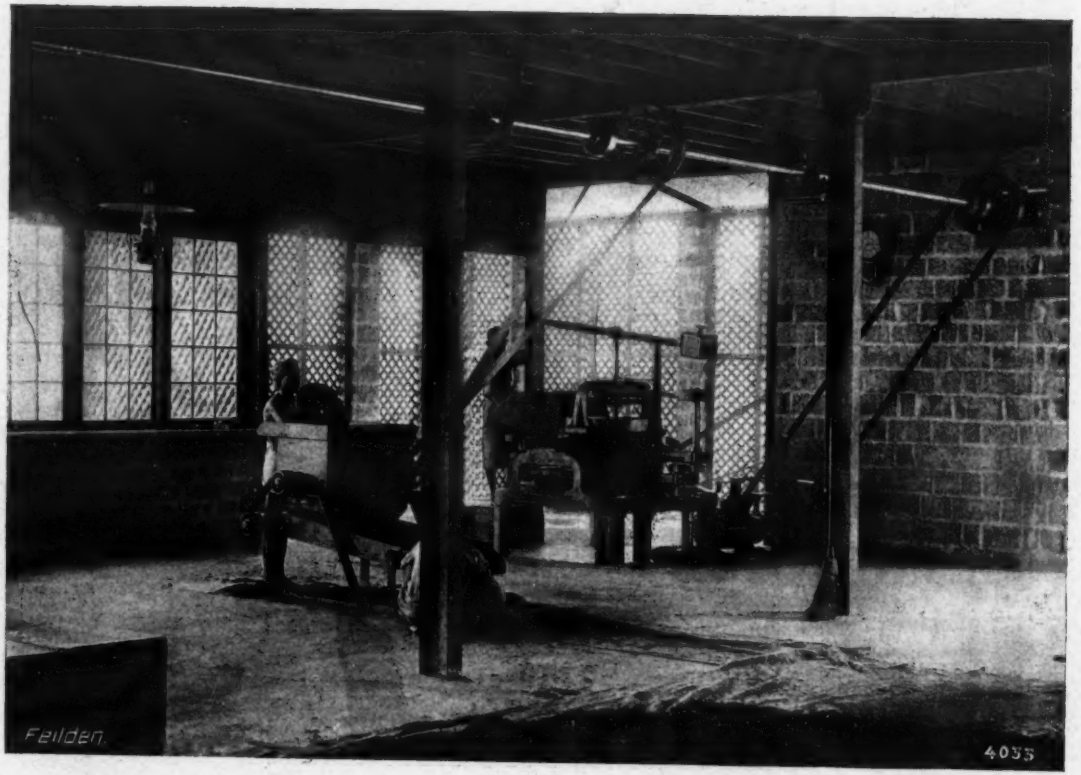


FIG. 34.—VIEW IN A FACTORY SHOWING MR. J. BROWN'S TRIPLE-ACTION TEA ROLLER.

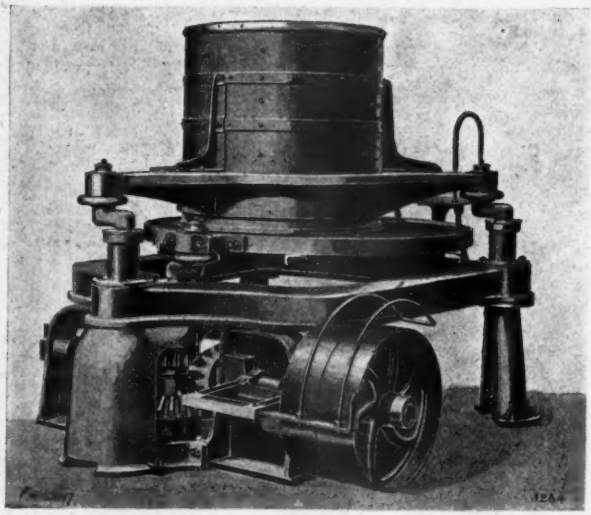


FIG. 35.—HENRY THOMPSON'S ROLLER.

among others, by removing the top coating of ½-in. boards from the table and filling in the space with a mixture of equal parts best portland cement and good fine sand, and setting under water. It is as well to mention "some success," because there were not a few instances where, inside 20 minutes, the carefully made coating had the appearance of a Japanese puzzle.

In 1887, Mr. Jackson brought out his "Rapid" roller (Fig. 33), and in the choice of the name appropriateness was certainly not wanting. The action of the machine will very readily be seen from the illustration. It is circular and following, and avoids much of the friction plainly visible in the cross-action models, the rolling cap jacket being free from the bottom table as in the Excelsior and Rajah machines.

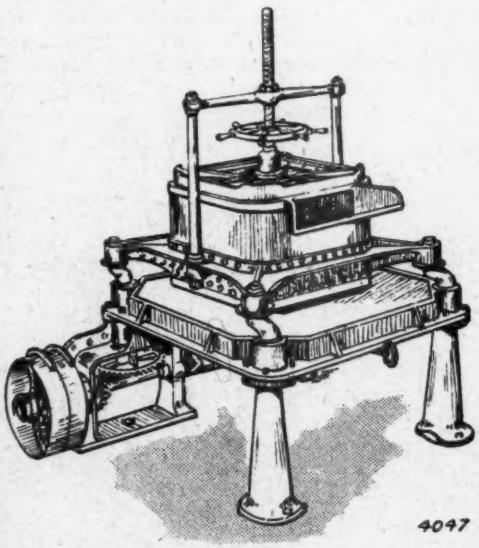


FIG. 36.—THE "BLAXTON" TEA ROLLING MACHINE.

The extreme simplicity of this machine may be said to have stamped it as a favourite from its first appearance. Factory buildings were becoming hopelessly inadequate to the exigencies of the crop, and additional rolling accommodation ordered in a hurry necessitated some scheming as to how to fix and drive the same. The arrangement of the driving bracket and bevel gearing enabled the body of the machine to be placed in any position, the driving bracket occupying some 3 ft. only, so that rapid rollers were wedged into all sorts of corners temporarily. Quality and quantity of output showed marked improvements on any previous roller.

Whether by way of improvement or coincidentally, Mr. Richardson, of Kinmond & Richardson, substituted plates of glass for the wood rolling surfaces. Details regarding the results of this experiment are not available.

In 1888 Mr. Henry Thompson placed a machine on the market, which has been somewhat altered since the original design was patented, and is now known as the open-top type (Fig. 35).

The top-rolling box is driven by a crank with two guiding cranks, and the bottom table has its motion imparted to it by means of a separate crank and span-gearing arrangement. The capacity of the machine is enormous—some 640 lbs. at a fill—and several very flattering testimonials have been received from users.

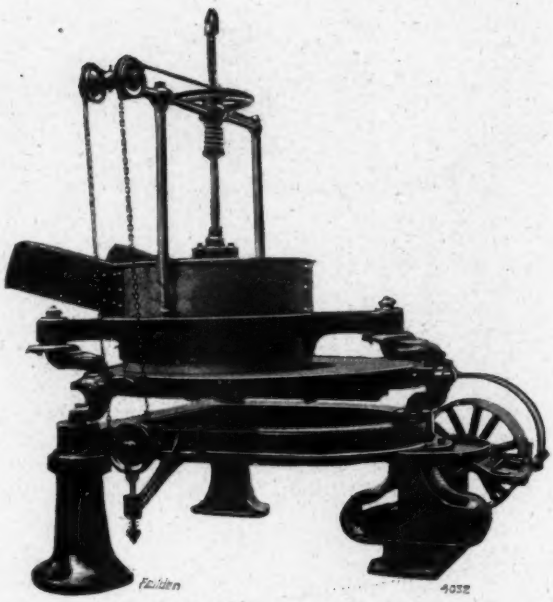


FIG. 37.—JACKSON'S LATEST LARGE SIZE "RAPID" ROLLER.

Mr. A. H. B. Sharpe introduced a system in 1888, in the shape of two horizontal surfaces having circular motion imparted by means of eccentrics. Information is not to hand whether the machine achieved a success or not; and it is, perhaps, hardly worth while speculating on this point. Prior to and just about this period the subject of tea-rolling was well in the minds of engineers and planters at home and in the East. Not the least energetic was Mr. William Jackson, and numerous are the improvements effected by him, notably a fan arrangement with a pipe connecting to the top rolling-box for cooling the leaf while rolling, and later an alteration in the shape of the rolling-cap which had hitherto been concave in form but was now made more convex with a view to facilitating the circulation of the leaf. These being among the many various alterations in detail of construction of the "Rapid" roller are duly chronicled, but the machine remained

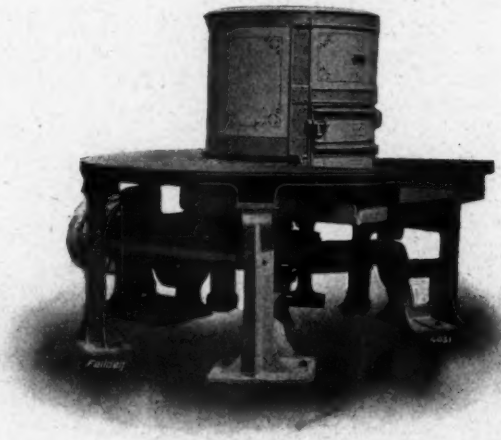


FIG. 38.—DAVIDSON'S OPEN-TOP ROLLER.

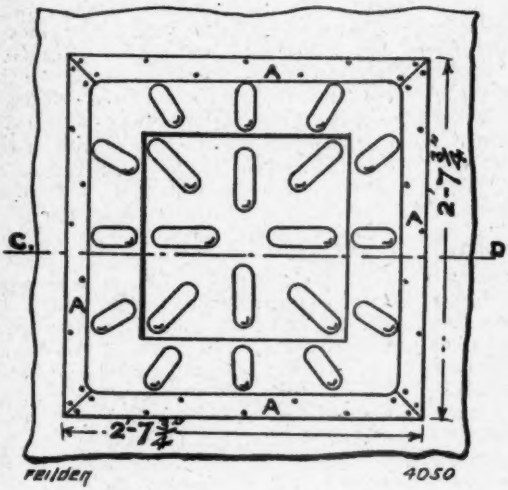


FIG. 39.—BRASS SHEETING AS USED IN ROLLING MACHINES.

to all intents and purposes pretty much as it was originally placed on the market. Many of the improvements and alterations were introduced to meet special demands.

In 1892, Mr. J. Brown, a Ceylon planter, brought out his "Triple-Action Tea Roller" (Fig. 34), for which a long list of advantages were claimed, notably ventilation of the leaf when being rolled, both while running light or under heavy pressure, without the intervention of fans or blowers: improvements in quality and rapidity of work done and small consumption of power, easy adjustment of pressure on the leaf being among the more important.

L. H. Sutton in 1893 produced a machine with two rolling plates running in the same or opposite directions. The idea of rotating the rolling surfaces in opposition directions appears to have formed in the minds of not a few interested in tea-rolling machinery improvements, but we are inclined to think the ulterior desired effect is, by this motion not properly obtained. The action performed when rolling by hand appears to have been the correct one, and this was always of a continuous and following nature. The machines therefore embodying a similar action seem to have met with the largest measure of success.

A machine brought out by one of the Brothers Begg in Assam was for some years manufactured by Burn & Co. of Calcutta. It is now being turned out by the Blaxton Engineering Co., and has been renamed the "Blaxton" Roller (Fig. 36).

As already stated, the "Rapid" roller (William Jackson) has been subjected to various alterations and improvements, a few of which have been detailed. One of the latest types is shown in Fig. 37.

Mr. S. C. Davidson of "Sirocco" fame, had until 1895 and 1896 confined his attention to withering, and as will be seen later to other branches of machinery for use in tea manufacture. His 20,805 of 1895 and, subsequently, 8,834 of 1896, deal with an "Open-Top Tea-Rolling Machine" (Fig. 38), and set forth some important advantages. The leaf receptacle above the rolling table is stationary, thus reducing the number of working parts and consequent absorption of power. As in all rollers of the open-top type, the

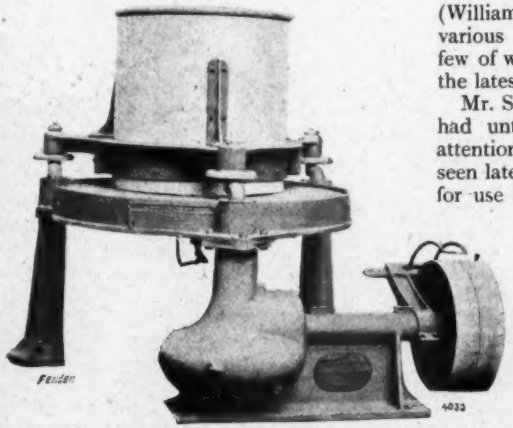


FIG. 40.—JACKSON'S SINGLE-ACTION RAPID AND GEAR CASING.

capacity is enormously great. The illustration is sufficiently self-explanatory in character to obviate the necessity for further and lengthy description.

It will be remembered that for years, during the early period of manufacture by machinery, wood was the only material considered suitable to be in contact with the leaf during the rolling process. This no one appeared inclined to dispute or even doubt, until the extra work to be performed by the machines found out the weak spots in the shape of continual repairs, and at very awkward times, also the difficulty of keeping the wooden parts sweet. Granite and marble were tried with varying success, and these in turn gave way to brass sheeting over the whole surface, and brass ribs, to which some further improvements were added by Messrs. Marshall Sons & Co., Ltd., to the machines made by them to Mr. Jackson's designs (Fig. 39). The shoulder-pieces of cast brass, as shown at *AA*, being found to wear out more quickly than the other surfaces, are made of somewhat heavier section and are renewable without difficulty.

We are able to call to mind the first of William Jackson's single-action rollers, with the top rolling caps of cast-iron. Rightly or wrongly, these were accused of discolouring the leaf and were soon discarded; some useful service was, however, found for them, as when turned upside down they made very excellent fire-places for managers' and assistants' bungalows on cold-weather evenings: this by the way. While no complaints are forthcoming regarding any deleterious effect produced by the brass on the leaf in the course of rolling, the advantages in the way of cleanliness and smooth running of the tables are manifest.

The patent single-action Rapid roller, (Fig. 40) designed by Mr. Jackson, has found a large number of users, where the leaf is particularly soft, or where slight withering is the rule; it is of the open-top type, and is capable of taking a very large fill at each operation. The casing for the bevel gearing presents a feature of novelty and improvement from a safety as well as a cleanly point of view. Accidents in factories to life and limb are happily not very frequent, and are invariably due to utter carelessness on the part of the injured; but when they do occur the Native press is ready to make the most of them. It is, therefore, well to run as few risks as possible, and it must be admitted, in this respect, that in all but a very few instances the utmost regard is most religiously paid. Any exception will generally be found on estates Native owned and Native managed.

(To be continued.)

H. J. Harding Fraser

Modern Portable Engines.

By WILLIAM FLETCHER, M.I.Mech.E.

In a previous issue of this magazine a brief account of the birth of the portable engine was given. In the present article the latest and best types of engines will be illustrated and described. The modern portable engine of the day, with its high-class multitubular boiler, is a marvellous production at so moderate a price. The design and workmanship will bear inspection, while the excellence of the materials employed in its construction are above suspicion. It may be thought that all the engines present a similar appearance, the leading makers have fallen into a beaten track; but this similarity of arrangement is undoubtedly the outcome of well-tried plans; no fault however, can be found with the beaten path when it leads to the highest results. The portable engine of the best British manufacturers is distinguished for symmetry of arrangement, excellent proportion of parts, simplicity of form, causing it to present a pleasing appearance. It must be remembered that a good appearance has a decided commercial value: it does not imply any so-called ornamentation or excess of bright work, much less the employment of fine colours. But it does demand that the metal is so placed that it will most advantageously meet the strains to which it will be subjected. Solidity and straightforwardness are cardinal virtues, and these will generally be found in the machinery to be dealt with herein.

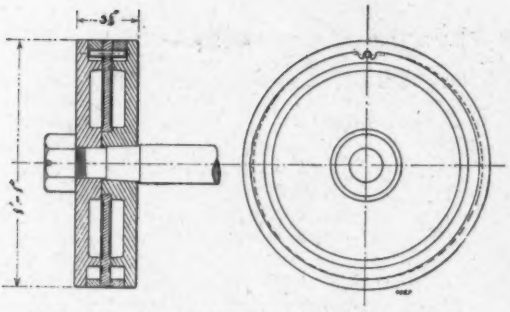
Most of the makers claim for their engines some leading characteristic which possesses advantages over the productions of their competitors. Some of these devices will be sought out and referred to as we proceed.

Messrs. Brown & May, of Devizes, are the makers of the compound portable engine shewn by Figs. 1 and 2. The engine is fitted with a Pickering governor, acting directly on to an equilibrium throttle-valve, and is designed for a working pressure of 140 lbs. per sq. inch. The cylinders are steam jacketed, and properly drained; the front cylinder-covers have trunks cast on to them, which are bored to form the piston guides. It will be seen that the valve chests are placed outside the cylinders: the slide valves are easily accessible for setting, examination, or repairs. Between the two elastic rings of the piston, a plate is fitted like Figs. 3 and 4.

A piston slide-valve is used on the high-pressure side of the cylinder, and for the low-pressure cylinder an ordinary slide-valve is used. The eccentric straps are made of tough cast-iron, which is a far more suitable material than brass for the purpose; the eccentrics are fixed to discs by bolts, and arranged so that the engine can be made to run in either direction. Tee-ended connecting-rods are used; the brasses, at the large end, are secured by two bolts and a wrought-iron plate. Cast-iron crankshaft brackets are employed, having the carriages set at an angle, so as to compensate for wear in either direction. The undersides of the carriages are planed and fitted to the brackets; and they have a slight horizontal movement, to allow for the expansion of the boiler when steam is up; the carriages are held securely at a uniform distance from the cylinder by wrought-iron stay-bars, as shewn in Fig. 1.

The feed-pump is arranged to work continuously, to pump hot or cold water, and to admit of the return of the whole or part of the water into the supply tank as required; the pump cock can be set so as to keep the water-line in the boiler at the mean level.

The engine under notice is fitted with a combined feed-water heater and grease separator; a pipe is provided for conducting the condensed steam and grease (coming from the cylinder) to the ashpan; and with an arrangement permitting clean steam to come in contact with the overflow



FIGS. 3 AND 4.—DETAILS OF MESSRS. BROWN AND MAY'S PISTON.

water from the pump, thus slightly heating the feed-water prior to its further heating in a chamber under the check-valve. This apparatus is illustrated by Figs. 5 to 8.

Another special feature applied by Messrs. Brown and May is their patent tube-cleaner. This apparatus is fixed on the firebox shell, in a convenient position, and arranged to introduce a blast of steam suddenly into the chimney: thus setting up a powerful draught through the boiler tubes which instantly clears them of all soot and ashes. The engine is mounted on wrought-iron travelling wheels.

The general dimensions of the 12-h.p. compound engine and boiler are as follows :—

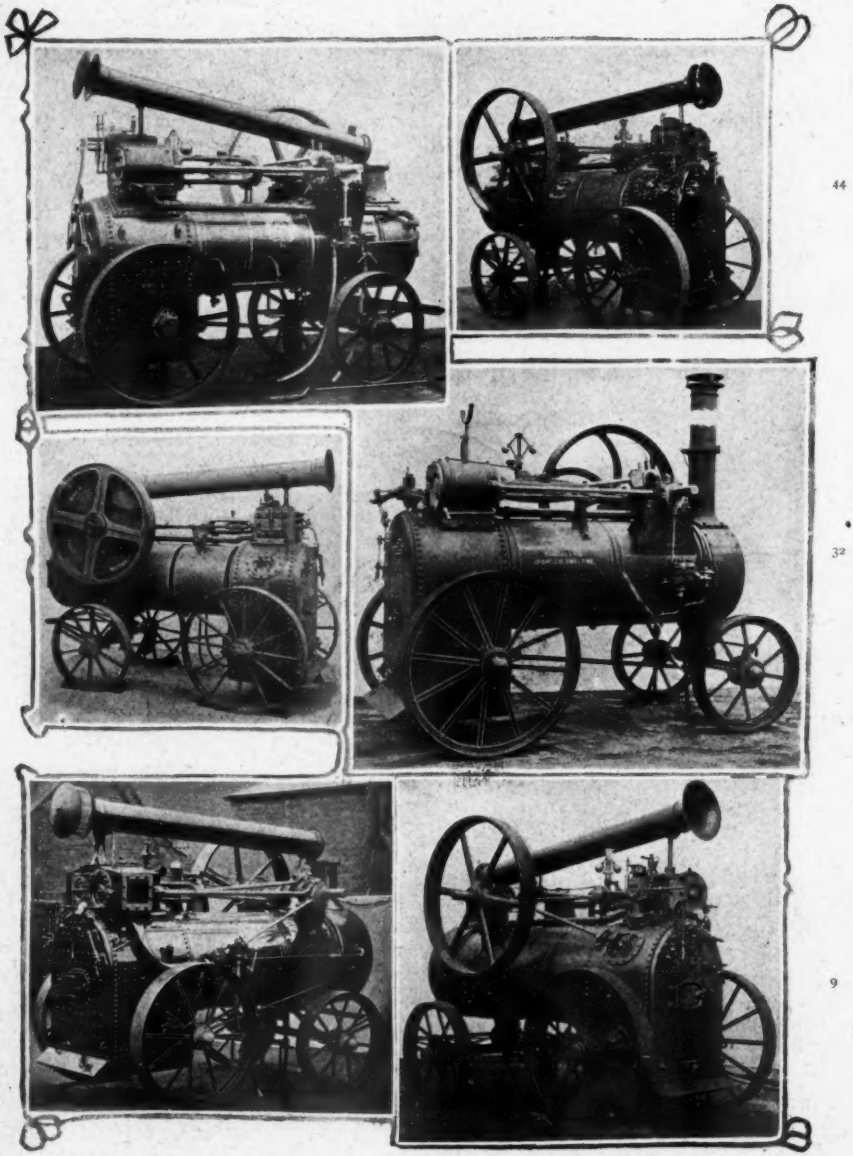
Diameter of high-pressure cylinder	7 ins.
Diameter of low-pressure cylinder	12 ,,
Stroke of both pistons	12 ,,
Diameter of fly-wheel	4 ft. 6 ,,
Width of fly-wheel	9 ,,
Revolutions per minute	180
Diameter of crank-shaft (in bracket bearing)	3½ ins.
Diameter of boiler barrel	3 ft. 1 in.
Length of boiler barrel	6 ,, 7½ ins.
Length of outer firebox	3 ,, 2 ,,
Length of inner firebox	2 ,, 8¼ ,,
Width of outer firebox	3 ,, 6½ ,,
Width of inner firebox	3 ,, 0⅝ ,,
Height of outer firebox	4 ,, 5¾ ,,
Height of inner firebox	3 ,, 0 ,,
Total length of boiler	11 ,, 9 ,,
Number of tubes	45
Diameter of tubes	2½ ins.
Heating surface in tubes	204·7 sq. ft.
Heating surface in firebox	35·8 ,,
Total heating surface	240·5 ,,
Grate area	7·9 ,,
Heating surface per nominal h.p.	17

During exhaustive trials on Messrs. Brown & May's works, this type of engine has proved to be satisfactory as regards running, and particularly economical.

The coal consumption during a day's run being 2·77 lbs. of coal per b.h.p., when the engine was developing over 40 h.p. This is more than the makers intend the engine to do, they usually consider the maximum effective h.p. as 2½ times the nominal, that would be 30 h.p. on the brake.

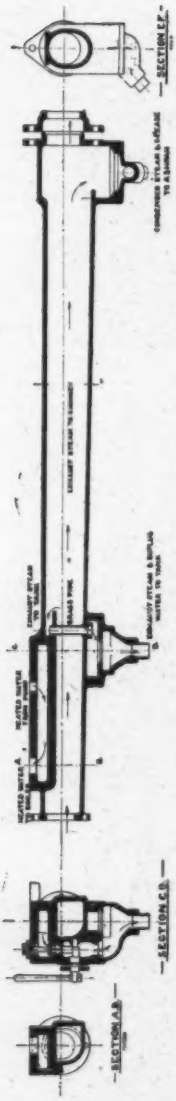
The output of portable engines by British firms in the face of foreign competition, is simply enormous. Messrs. Clayton & Shuttleworth of Lincoln, for instance, have manufactured upwards of 33,300 engines, mostly of the portable type. Their works for some years past have been pressed to their utmost capacity, to meet the prodigious demand which exists for their productions in every part of the globe.

Fig. 9 shews the fly-wheel side of one of their standard type of single-cylinder engines, fitted with cross-arm governors acting on an equilibrium throttle-valve. Both the boiler and cylinder of all Messrs. Clayton & Shuttleworth's engines



45 44 42 32 1 9

FIGS. 1, 9, 32, 42, 44, 45.



FIGS. 5, 6, 7, 8.—DETAILS OF MESSRS. BROWN AND MAY'S WATER HEATER.

are large enough to easily develop three times the nominal horse-power on the brake, while running at a moderate speed. The portable engines of four-horse power and upwards are tested under steam pressure at 90 lbs. per sq. inch on a friction brake, to not less than three times their nominal power; and the boilers under hydraulic pressure at 165 lbs. per sq. inch. Every engine is subjected to a long and crucial trial, until the utmost efficiency is reached, as regards economy, power, good governing, and a minimum amount of friction; the cylinder bore, piston, and the slide-valve faces are brought to a perfect surface; in many cases, the results of the trials are tabulated, and kept for future reference and comparison.

The cylinder is made of a special quality of hard close-grained iron. The working barrel or liner is cast separately, and tightly forced into position by hydraulic pressure; the annular space between the liner and shell forms a most efficient steam-jacket. All their portable engines are now made with a flat base, truly planed

FIG. 10.—MESSRS. CLAYTON AND SHUTTLEWORTH'S VARIABLE EXPANSION ECCENTRIC.

and fitted to a planed saddle secured by turned bolts. This method of attachment enables the cylinder to be removed for reboring, or for repairs, and to be replaced by unskilled labour. By means of the variable eccentric sheaves, shewn by Fig. 10, the cut-off can be varied according to the load on the engine, and the maximum economical effect obtained. The crankshaft carriages are connected to the cylinder on one side, and to the firebox crown on the other, by wrought-iron stays; thus maintaining the required distance between the centres. The carriages are planed on the bottom, and mounted on saddle brackets

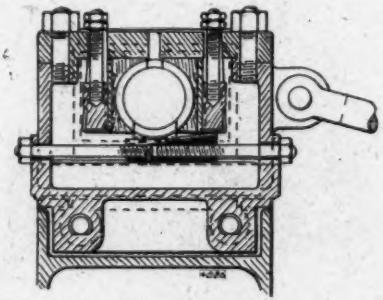
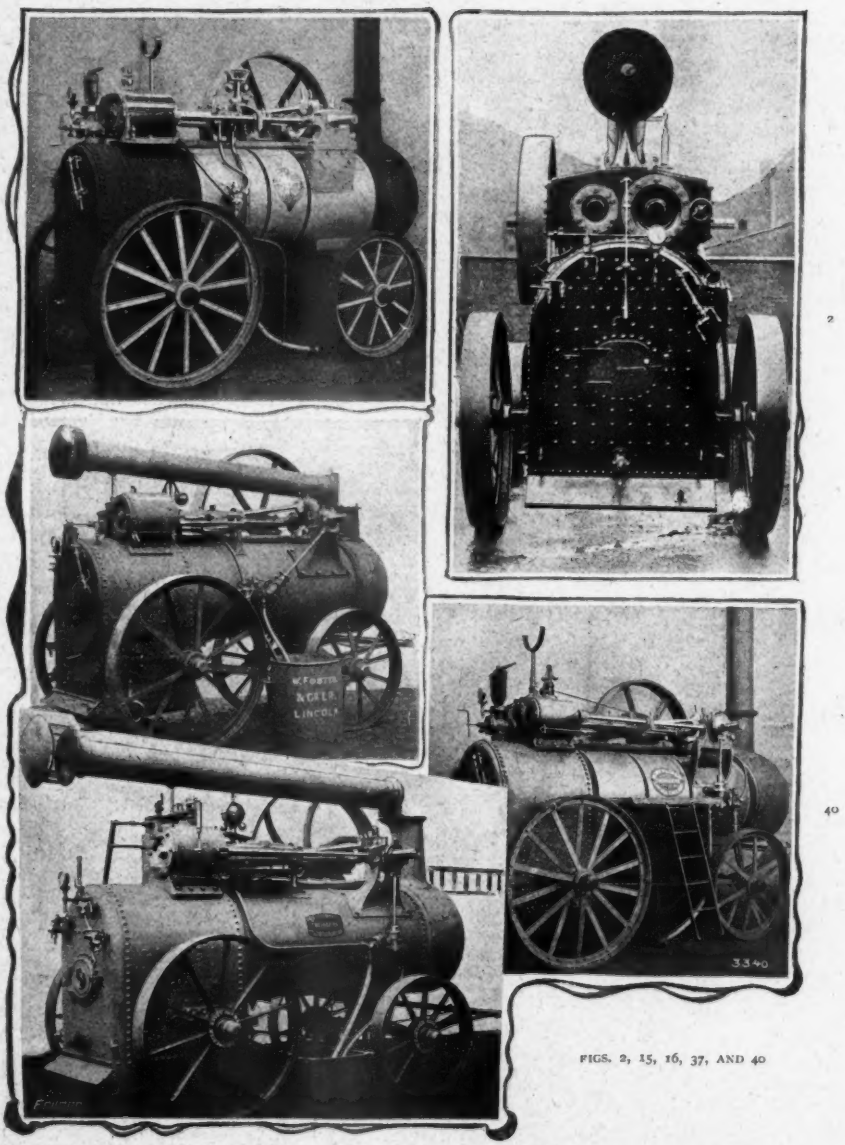


FIG. 11.—DETAILS OF MESSRS. CLAYTON AND SHUTTLEWORTH'S CRANK SHAFT BRACKET.



37 2 16 40 15

FIGS. 2, 15, 16, 37, AND 40

bolted to the boiler. By this method of construction the crankshaft brackets, bearings, and stays relieve the boiler from all racking strains, caused by the working of the engine; and allow the boiler to expand and contract under every change of temperature, without altering the distance between the crankshaft and the cylinder. Fig. 11 shows a section of the crankshaft bracket for the fly-wheel side. The engine shewn is fitted with cast-iron crankshaft saddle-brackets, but steel-plate brackets are also used; the latter are lighter and, being riveted to the boiler, they form a much better joint than a bolted connection. The feed-pump is of much larger

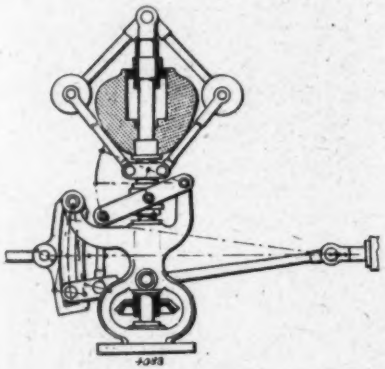


FIG. 13.—DETAILS OF MESSRS. CLAYTON AND SHUTTLEWORTH'S AUTOMATIC EXPANSION GEAR.

capacity than what is actually required to supply the boiler. A regulating cock is arranged on its discharge branch, which can be adjusted for a continuous supply to the boiler, according to the load on the engine. Most of the engines are mounted on wrought-iron travelling wheels, and all the fore carriages are made of wrought-iron.

Fig. 12 shews a smaller portable engine manufactured by Messrs. Clayton & Shuttleworth. In this instance cross-arm governors control the speed of the engine by means of an equilibrium throttle-valve. The crankshaft carriages are mounted on steel-plate brackets, the construction of which is clearly shewn in the illustration. A steel plate seat is provided for the cylinder, planed to suit. It will be noticed that a bored cylindrical guide takes the place of the usual four-slide bars: these trunks are coming into general use among the makers. The wrought-iron under-carriage, the travelling wheels, and the chimney raiser are clearly depicted in the illustration. Many of the firm's portable engines are fitted with their patent automatic expansion-gear, as represented by Fig. 13, by means of which the speed of the engine is controlled directly by the governor; which, as it rises, lifts the die in the link, reducing the travel of the expansion valve, and thus cutting off the supply of steam earlier in the stroke whenever the speed tends to increase, and *vice versâ*.

Fig. 14 represents the celebrated compound portable engine made by Messrs. Davey, Paxman & Co., of Colchester, which carried off the £100 prize at the trials of the R.A.S.E. at Newcastle, 1887. It will be seen that the engine is erected on a light channel iron frame; the frame is connected to wrought-iron brackets, which are riveted to the boiler, as shown. Automatic expansion-gear is fitted to the high-pressure cylinder; the governors are patented by the firm, and used on many of their engines. Every pound of superfluous weight is removed from the working parts, so as to secure the most economical results. The boiler is of large dimensions, and neatly cased all over, to prevent the loss of heat. Steam is conducted to the cylinder through the stop-valve casing as shown, the stop-valve and the check-valve are the only two connections opening into the boiler.

The table on page 52 gives some interesting figures obtained during the trials at Newcastle.

Fig. 15 shows one of Messrs. Davey, Paxman & Co.'s single-cylinder engines fitted with automatic expansion gear controlled by their patent governor. The cast-iron crank-shaft brackets are connected to the cylinder by a stay-bar. It will be noticed that the boiler front plate is flanged to a large radius, so that the mudholes can be placed in the corners, which facilitates the

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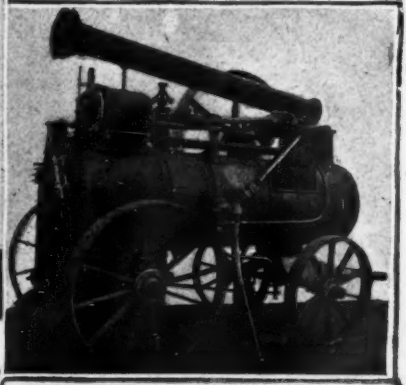

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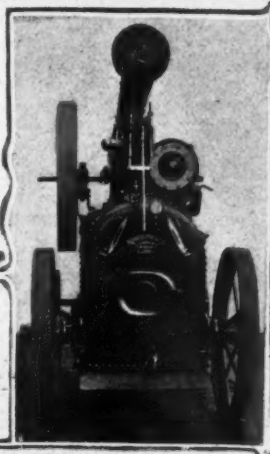

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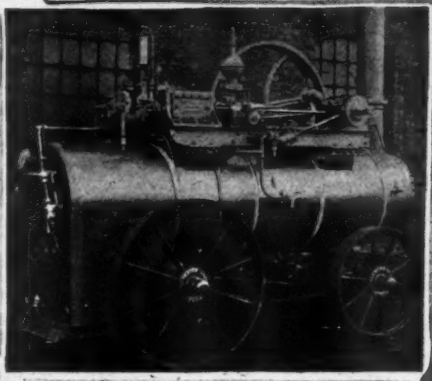

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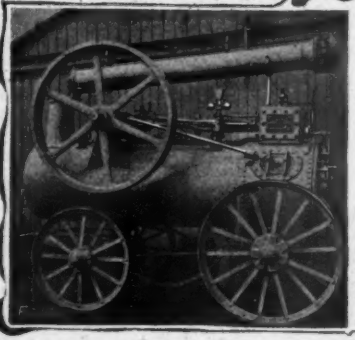

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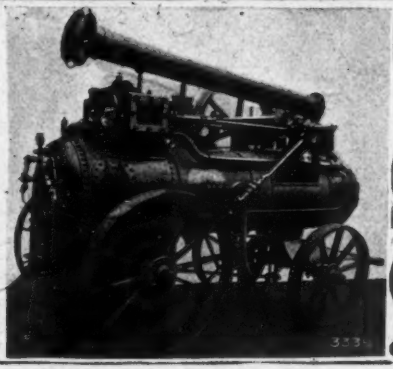


FIGS. 12, 14, 22, 26, 27, AND 47.

DIMENSIONS OF SINGLE-CYLINDER PORTABLE ENGINES.

Nominal Horse-Power.	Effective Horse-Power.	Diameter of Cylinder.	Length of Stroke.	Revolutions per Minute.	Diameter of Fly-Wheel.
3	7	6½″	9″	180	4′ 0″
4	12	7″	10″	150	4′ 8″
5	15	7¾″	12″	140	5′ 0″
6	18	8½″	12″	140	5′ 0″
7	21	9″	12″	140	5′ 0″
8	24	10″	12″	140	5′ 0″
10	30	11″	14″	127	5′ 6″
12	36	12″	16″	127	5′ 6″
14	42	13″	16″	127	5′ 6″

DIMENSIONS OF DOUBLE-CYLINDER PORTABLE ENGINES.

Nominal Horse-Power.	Effective Horse-Power.	Diameter of Cylinders.	Length of Stroke.	Revolutions per Minute.	Diameter of Fly-Wheel.
8	24	7″	12″	140	5′ 0″
10	30	7¾″	12″	140	5′ 0″
12	36	8½″	12″	127	5′ 6″
14	42	9″	14″	127	5′ 6″
16	48	10″	14″	127	5′ 6″
20	60	11″	14″	116	6′ 0″
25	75	12½″	16″	116	6′ 0″
30	90	13″	18″	100	7′ 0″

Maker.	Pounds of Coal per Brake-Horse-Power per hour.		Difference.	Percentage of Advantage in favour of Compound System.
	Simple.	Compound.		
Davey Paxman - -	2·6	1·85	·75	28·9 per cent.
Foden - - -	2·76	1·94	·82	29·7 ,, ,,
McLaren - - -	2·68	2·18	·50	18·6 ,, ,,

raking out of the sediment from the bottom of the fire-box water space. A feed water heating apparatus is applied, of the usual open type.

Messrs. W. Foster & Co., Ltd., of Lincoln, are the makers of the portable engine illustrated by Fig. 16. It will be seen that the governors are of the slow speed type; they act directly on a gun-metal equilibrium throttle-valve fixed in the steam passage to the cylinder. The crankshaft brackets are of cast-iron of the usual type. The feed-water heater consists of a copper branch from the exhaust-pipe, connected with a three-way cock at the overflow from the pump, arranged so that the overflow water, on mingling and uniting with the exhaust steam from the cylinder, condenses and passes down with it to the feed-water cistern, thus raising the temperature of the feed-water to nearly boiling point.

A standard type of portable engine manufactured by Messrs. Richard Garrett & Sons, Ltd., of Leiston. The engine is fitted with the Turner-Hartnell shaft

governor in combination with a single slide-valve, the action of which is, when the load upon the engine is reduced and the tendency is to increase in speed, the governor acts direct upon the eccentric, reduces the travel of the valve, and increases the angle of advance so as to cut off steam at an earlier part of the stroke, and thereby increase the ratio of expansion. When the load upon the engine is increased, the operation is reversed, the steam is cut off later in the stroke, and the ratio of expansion is reduced. A flanged steel-plate saddle is a distinctive feature of the engines made by the Leiston firm. Fig. 17 shows the arrangement: this saddle affords a support for two or three pedestals for carrying the crankshaft. A screw-down brake, acting on one hind travelling-wheel, is fitted. The lever for raising and lowering the chimney is fitted to the joint-ring. A compound portable engine is also made by Messrs. Garrett, the high-pressure slide-valve of which is actuated by the Turner-Hartnell governor. The bored guides for the cross-heads are used instead of the four-slide bars. This engine is fitted with a central bearing to the crankshaft, mounted upon the steel-plate saddle. Ladders and platforms are provided on each side of the firebox for gaining access to the cylinders, etc., for oiling, cleaning, or adjustment of the working parts A chimney raiser is also fitted. A section of Messrs. Garrett's water-heating apparatus is shown by Fig. 18, which is self explanatory. The fore-carriage and under-gear are formed of flanged plates; the lower part of fore-carriage and splinter-bar for shafts is shown by Figs. 19, 20, and 21; the method of construction will be seen from the figures.

Fig. 22 shows the fly-wheel side of a portable engine by Messrs. R. Hornsby & Sons, Ltd., of Grantham. The engine is fitted with cross-arm governors, actuating a

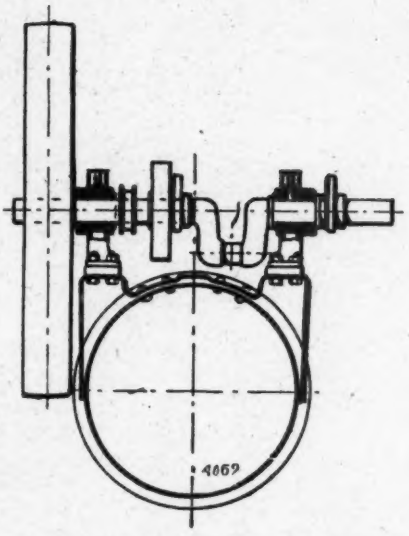


FIG. 17.—DETAILS OF MESSRS. GARRETT'S STEEL SADDLE.

throttle valve in the usual manner. It will be seen that the crankshaft bearings are supported on wrought-iron horn plates, or brackets, like Fig. 23. The bearings are held rigidly in position by two stay

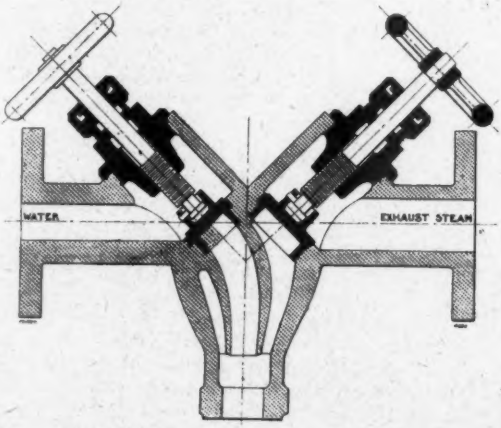
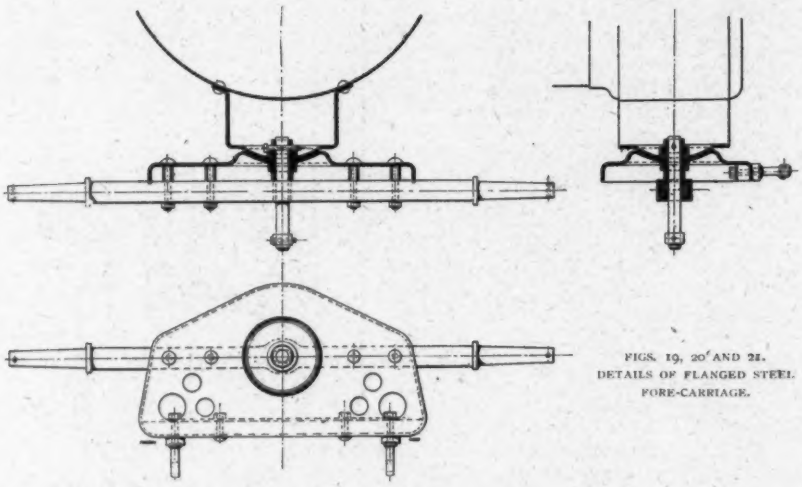


FIG. 18.—DETAILS OF MESSRS. GARRETT'S WATER-HEATING APPARATUS.



FIGS. 19, 20 AND 21.
DETAILS OF FLANGED STEEL FORE-CARRIAGE.

bars, one of which is secured to the cylinder, and the other is attached to a lug bolted to the arch plate. The sides of the firebox shell are continued downwards beyond the foundation frame for carrying the ashpan, thereby doing away with angle-pieces riveted to the firebox and the ashpan. Wrought-iron wheels are used, the spokes are riveted between two angle-iron rings, the tyre is shrunk on to the double angle iron, and riveted.

An engine fitted with Hornsby & Edward's patent automatic expansion gear is illustrated by Fig. 24. A high-speed Porter type of governor regulates the position of the die and valve eccentric rod, cutting off steam by a separate slide-valve on the back of the main-valve according to the load on the engine. In order to prevent the vibrating movement of the slot link from affecting the action of the governor, a small eccentric is employed: the eccentric acts very powerfully to shift the die, but the die can do very little to shift the eccentric and make the governor hurt. It is a well-known fact that the eccentric makes a good driver, but it is very difficult to drive it. The

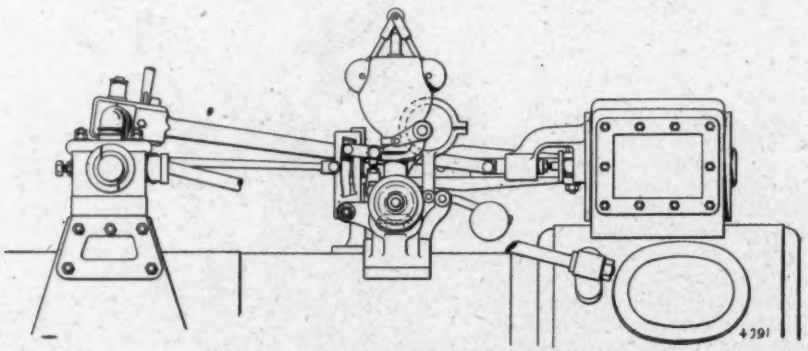


FIG 23.—DETAILS OF A PORTABLE ENGINE BY MESSRS. HORNSBY AND SONS.

engine is similar, in many particulars, to the one just described; but the wrought-iron travelling wheels are made in a different manner, clearly shewn in the illustration. Fig. 25 shews a plan of the engine fitted with automatic expansion-gear.

Messrs. Marshall, Sons & Co., of Gainsborough, are the manufacturers of the portable engine represented by Fig. 26. The engine is fitted with cross-arm high-speed governors, actuating a throttle-valve for controlling the revolutions of the engine. Steel crank-shaft brackets are used, which are double riveted to the boiler barrel, supporting strong carriages bolted thereto with turned bolts; the brackets take a large bearing on the boiler, obviating the possibility of leakage, and are stronger and lighter than cast-iron brackets. No side stay-bars are shown on this engine. The pump is bolted to a steel flanged seating riveted on the boiler, faced to receive the pump, and projecting beyond the lagging, so that the pump can be readily removed if required Every engine is fitted with a variable expansion eccentric, by means of which the steam admission can be varied from full power down to one fourth, with proportionate economy of fuel. It also forms a simple reversing apparatus. In the place of a wood fore-carriage, the turn-plate and attachment for the shafts are formed out of a flanged steel plate, with suitable connections to the axle.

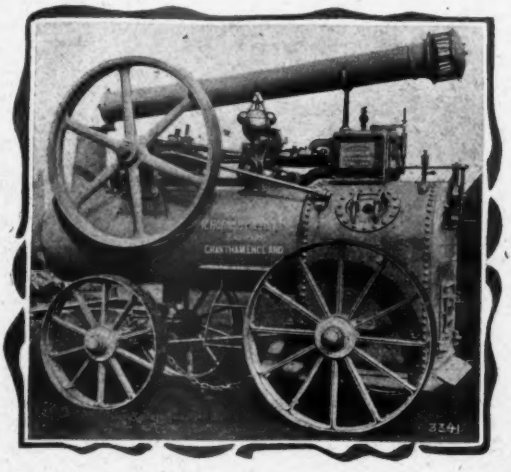


FIG. 24.

A compound portable engine is represented by Fig. 27, manufactured by Messrs. Marshall, Sons & Co., of Gainsborough. This type of engine has been specially designed to give the utmost economy that can be obtained in an engine of the portable type. The working pressure is 140 lbs. per square inch; at this pressure, and the standard speed, they will develop three times the nominal horse-power. The cylinders are mounted on planed steel girders, riveted on the shell of the boiler; the bottom of the cylinders are planed to fit on the girders; so the bolts connecting the cylinder foot to the girders are arranged outside the boiler. There is a brass connection on a separate riveted fixing, to convey steam to the cylinder. This connection is covered with non-conducting composition, the whole being enclosed in a neat casting so as to avoid all condensation; and the steam is taken to the top of the cylinder to ensure perfectly dry steam entering the cylinder. In order to secure the greatest possible stiffness in the crank-shaft, and steadiness in running, the crank-shaft is provided with a central bearing. The outside bearings are mounted on steel horn-plates as shown; and the central bearing is attached to a planed fixing, projecting above the lagging riveted to the boiler.

It will be seen that the pump is mounted on a steel fixing riveted to the boiler. From this description it will be perceived that no bolts enter the steam or water space of the boiler in any part. The front plate of the boiler is flanged to an

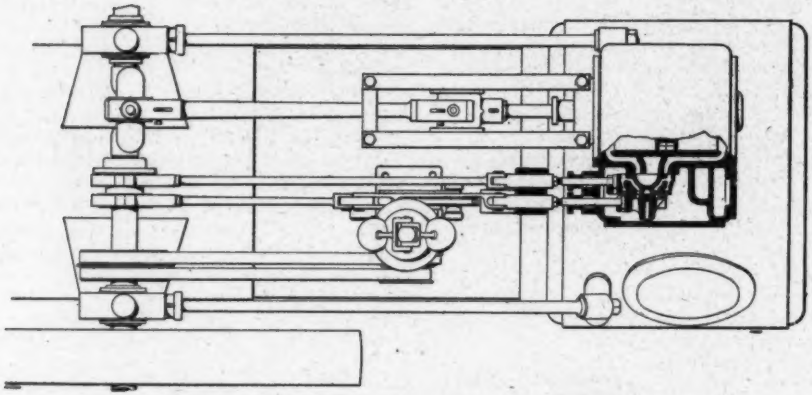


FIG. 25.—PLAN OF ENGINE BY MESSRS. HORNSBY AND SONS, FITTED WITH AUTOMATIC EXPANSION GEAR.

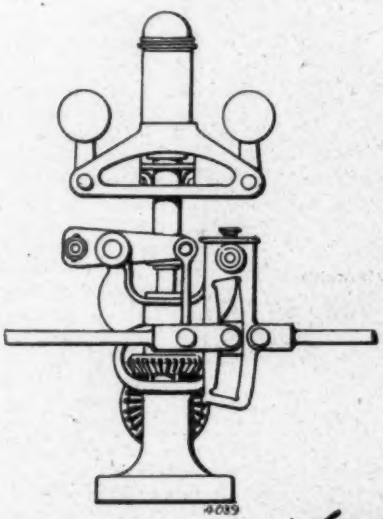


FIG. 28.—HARTNELL'S GOVERNOR AND AUTOMATIC EXPANSION GEAR.

exceptionally large radius, as shown. With the above engine Messrs. Marshall, Sons & Co. include a galvanised-iron tank, containing a copper coil for heating the feed-water without allowing it to come into direct contact with the exhaust steam: this is a valuable feature which is commendable.

The compound portable engine we have described is fitted with Hartnell's governor and automatic expansion gear to the high-pressure cylinder. Fig. 28 shows the arrangement, which consists of a highly sensitive governor acting through a link and die to a cut-off valve working on the back of the main valve. The speed of the engine is thoroughly controlled by means of the expansion valve, which regulates the admission of steam into the cylinder exactly in proportion to the duty performed by the engine.

W. Fletcher.

(To be concluded.)

Diagonal Engines for Paddle Steamers.

By GEO. HALLIDAY, Wh. Sch.

THE diagonal engine is the general type in use on modern paddle-steamers, but they are by no means all of the same design. Paddle steamers are built for a great many purposes, and the engineer has thus to modify the design of the engine to suit the boat, and the conditions under which the engine has to work.

The early diagonal engines were of the single-cylinder type; but that most commonly used at the present time is the compound diagonal side-wheel paddle engine. We will begin by describing a set of these, shown in Fig 1. They are fitted with a surface condenser. It will be seen that the cylinders are arranged so that their centre lines go through the centre line of the shaft at right angles, and that they are placed close together. The valve-chest of each cylinder is on the outside, and so the bodies of the cylinders are adjacent, and the two cranks are as near together as they can be. Ordinary D slide valves are fitted to distribute the steam, and these are actuated by the ordinary link and eccentric type of expansion gear.

The frame of the engine is of strong proportions, the material being of cast iron, and carefully designed to enable it to meet the severe strains to which it is subjected in the ordinary course of working. In order to maintain the maximum rigidity, the cylinders are bolted, not only to the engine-frame, but to the frame of the ship itself.

It will be seen from the figure, that the section of the engine framing along the base parallel to the bottom of the ship, is of T shape. Strong thick flanges are cast on this framing just immediately under the shaft. On these flanges are bolted the parts of the framing for supporting the shaft. In some cases where cost is a consideration, the surface condenser is fixed under the shaft and framing, or the shaft pedestals directly bolted to the surface condenser. But it can be easily understood that an arrangement which allows of the strains between the cylinder and the paddle-shaft to pass through and be taken up by the surface-condenser, is not a convenient one. Any flaw may exist in the casting of the condenser, and should its body give way, there is not merely a break-down of the engine, but one of the condensers as well; and, before work can be started again, the chances are that a new condenser will require to be provided.

In the arrangement of the framing of this engine, the framing to support the shaft is made separate from the rest of the framing, so as to ensure good casting, and it is bolted to the thick flanges on the base framing, and not to the condenser. To further tie the framing together, strong standards of forged steel connect the framing support, the shaft and the cylinders. These standards bolt and tie the cylinders and shaft together, connecting them rigidly. The standards also serve as direct transmitters of the forces which are in action between the cylinders and shaft, and so save the base and shaft framing from the great breaking strains which would otherwise come on them.

It will be seen also that the standards are made to serve another purpose. They are so formed and machined as to become guides for the cross-heads of the piston-rods of the engines.

The cylinders are of large size. The high-pressure cylinder is of 19 ins. diameter, and the low-pressure cylinder 38 ins., and they have a common stroke of 36 ins.

Care has been taken to make the working of the engine as convenient to the engineer as possible, and for this purpose it has been arranged that the operating lever and handles for controlling the engine should be in one place. Both the levers and handles for reversing and starting the engine are above on the starting platform. The reversing of the engine is in this case done by hand, and

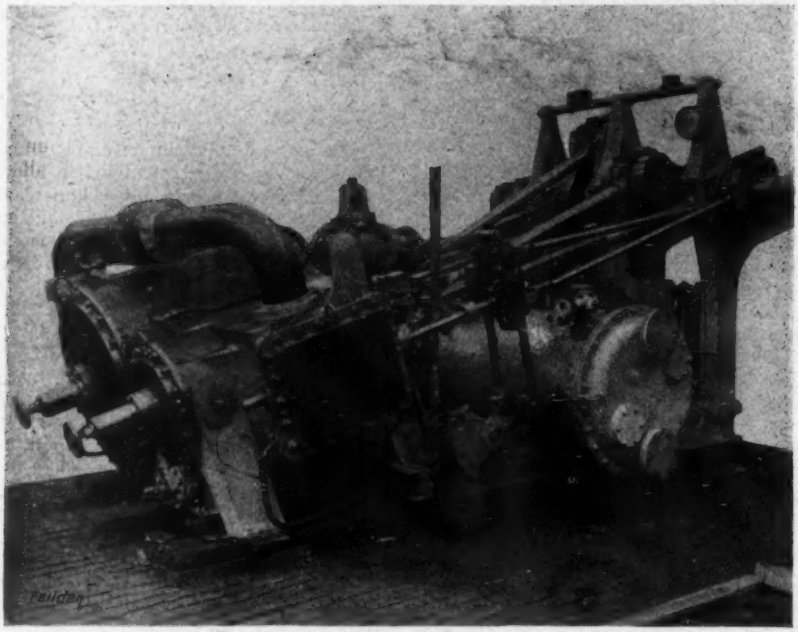


FIG. 1.—360-I.H.P. COMPOUND DIAGONAL SIDE-WHEEL ENGINES.

a hand-wheel is provided for this purpose, which revolves a spindle on which is keyed a worm. This worm actuates the reversing quadrant which is shown in the front of the photograph of the engine.

Space is of the utmost consequence on board these paddle steamers, and diagonal engines have been so designed that a pair of compound cylinders, allowing two expansions of the steam, take up little more room than one cylinder. In such a design the high-pressure cylinder is superimposed on the low-pressure cylinder. Such a set of engines are shown in Fig. 2. It will be observed that the centre lines of the engines are in the same vertical plane, instead of, as is usual, in the same inclined or diagonal plane. And, although they are in the same vertical plane, they are not parallel to one another, but converge on the same crank pin. Being inclined to one another, the connecting rods can never be at the same time in line with the common crank, hence there can be no dead point in such a set of engines. The crank will always be inclined to, at least, one of the connecting rods. Where there is plenty of room across the beam of the boat, it is easy to arrange for two sets of such engines to act on the same crank-shaft. As one set gives a very good distribution of turning moment on the crank-shaft; two sets, each set acting on its own crank-pin, produce a very much better turning moment, especially if the two cranks are at right angles to each other, or, better still, if opposite each other.

The arrangement shown in Fig. 2 has been adopted for the machinery of a ship which has a narrow beam. Such a set of engines can be fitted into the usual width of one; yet the presence of the upper cylinder and its effect on the crank-shaft

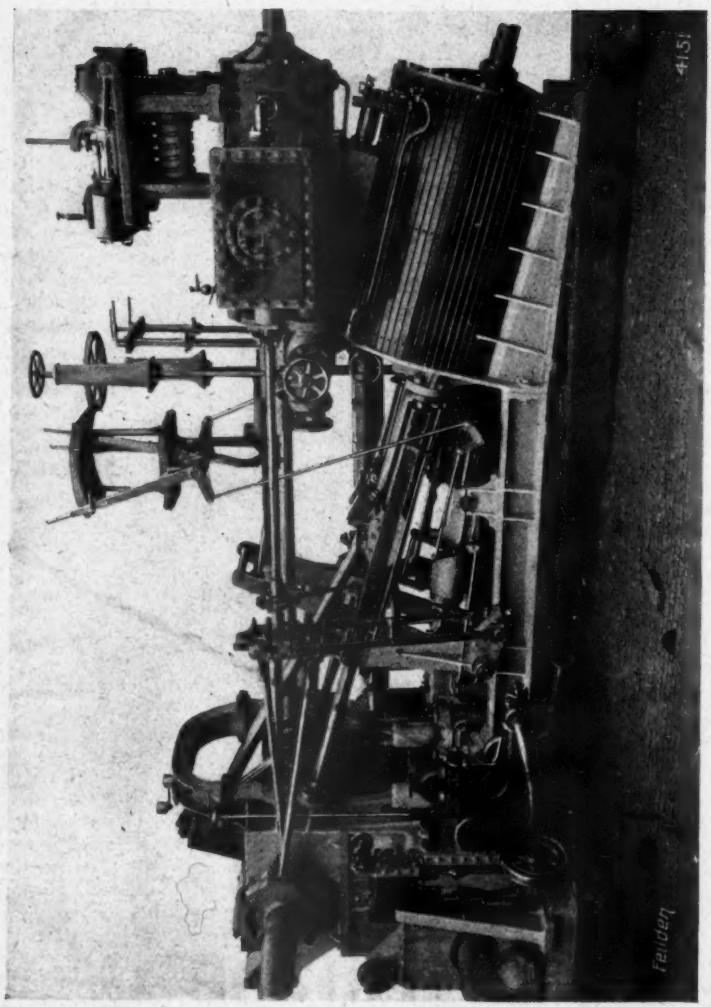


FIG. 2.—SUPERIMPOSED TWO-CYLINDER COMPOUND DIAGONAL SIDE-WHEEL ENGINE.

are to bring in the advantage gained when the dead-centre trouble is taken from the single-cylinder engine.

In this particular set of engines, the diameter of the upper high-pressure cylinder is 22 ins., while that of the lower low-pressure cylinder is 43 ins. The crank being the same length for each, they have common stroke of 54 ins. In this particular set, lightness and economy have been aimed at. The condenser has been made to do duty for framing to support the crank-shaft. For this purpose facings have been cast on the top of the condenser, so that the bearings of the crank-shaft might rest on and be bolted to them. The condenser is of the surface-condensing type, and is of cast-iron. The framing connecting the cylinders and the condenser are also of cast-iron. In order that the requisite rigidity may be preserved between the cylinders and the crank-shaft bearing blocks, strong forged steel standards are fixed between them; these standards also serve as guides for the piston-rod cross-heads.

The crank-shaft is of the overhung type. But there has been a peculiar arrangement between the crank-pins. The h.-p. and l.-p. crank-pins are coupled together by means of a forged steel connecting link. The valve motion of this type of engine is of the ordinary link-motion type.

The valves are of the common D type, fitted with relief rings, and both hand and steam reversing gear is fitted.

Everything has been so arranged in this engine as to render it as compact as possible. A merely cursory inspection of the photograph will make this very plain.

For example, the high-pressure cylinder, which itself is carried by the low-pressure cylinder, is utilised to carry the steam steering gear. The machine above the high-pressure cylinder is the steam steering gear engine. Then the air-pump is fitted between the engine-framing close to the condenser, while the feed and bilge pumps are fitted to the side of the air-pump, and are worked off the same crosshead.

It is often desirable to be able to work one paddle-wheel quite independently of the other: as, for instance, when one paddle-wheel breaks down or is disabled.

One of the methods by which independent action is given each paddle-wheel, is shown in the set of engines illustrated by Fig. 3. This set of engines is of the double compound condensing side paddle-wheel type, each engine being so arranged that one wheel can be worked if it should be required, while the other remains standing or working at a different speed in the same or in the reverse direction. This arrangement affords great facilitates for the quick manœuvring of the vessel. In another type the shafts of the two paddle-wheels meet in line, and are connected by a disengaging clutch. When connected with the clutch, they rotate at the same speed.

Each set of engines has a high-pressure cylinder of 16 ins. diameter, and a low-pressure cylinder of 30 ins. diameter, with a common stroke of 42 ins. The slide valves are of the ordinary D type, and ordinary link-motion valve-gear actuates them from the crank-shaft by eccentrics.

The framing, which is cast-iron, is of the girder form and section, and to it the cylinders are strongly bolted. The framing which supports the crank-shaft is separate from the base framing, thus reducing to a minimum the risk of developing any initial strains. This latter framing is strongly bolted to the base, and to the ship's framing. To take the strain between the cylinders and shaft, strong forged-steel standards are bolted between them, and these standards are so formed as to serve as guides to the crossheads of the piston.

In these pair of engines the condenser, which serves both engines, is separate from the framing. The material of which it is made is galvanised steel plate. It is bolted firmly to the base framing on to suitable parts made in the castings to take it immediately in front of the shaft framing. In front of the condenser, and connected with it by suitable pipes, are the air and circulating pumps, which are of the horizontal duplex type. The feed and bilge pumps are actuated by separate engines.

On rivers, such as the upper reaches of

the Nile, the Congo and South American rivers, where the vegetation which grows on the surface of the water is very rank, the boat is fitted with a single paddle-wheel in the stern. The width of the track of the boat is not great, and the draught is very small, often only 9 or 10 ins. In such a case as a stern wheel paddle boat, the engine cannot be placed in the middle of the boat, since the crank cannot be placed in the middle of the paddle-wheel shaft. Two engines have to be employed to drive such a paddle-wheel, one situated on each side of the boat, driving a crank on its own side of the wheel. In some cases these engines are placed near the stern, and the boiler well forward, so as to obtain the right trim of the boat. Many of these engines used for stern-wheel paddle boats are simple engines; but some of them, such as that we illustrate, are of the compound tandem type.

This set of engines thus show (Fig. 6) the modifications which require to be introduced to the ordinary diagonal side-paddle steam-engines, to enable them to suit the special conditions. Each engine is complete in itself, and is of the compound diagonal surface-condensing type. Each connecting-rod is connected up to the crank-pin at the end of the paddle-wheel shaft, on which can be seen the two keyed plates for the arms of the paddle-wheel.

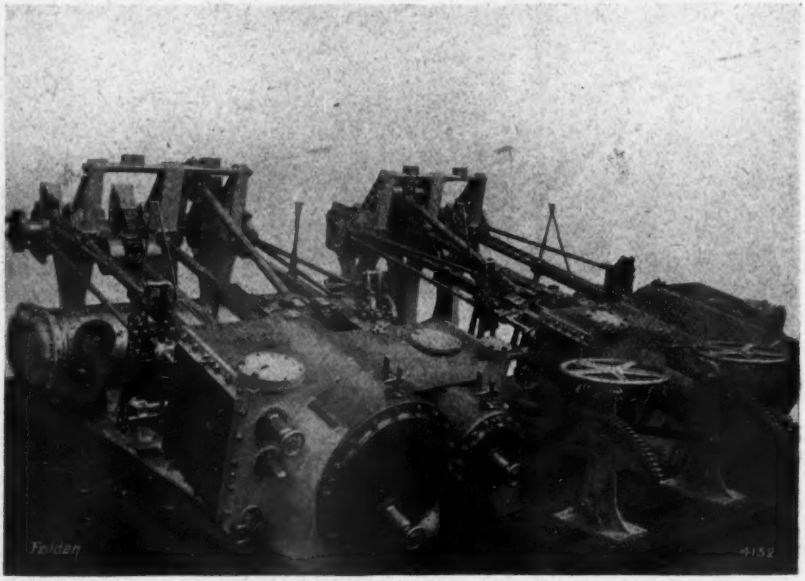


FIG. 3.—DOUBLE TWO-CYLINDER COMPOUND DIAGONAL SIDE-WHEEL ENGINE.

The framing, which is of cast-iron and of girder shape, carries the paddle-wheel shaft at one end and is strongly bolted to the cylinders at the other. The cylinders are bolted down to the ship's framing, which makes framing of engine cylinders, and framing of ship one rigid piece. The cranks, which are driven by the engines, are outside the frames and overhung.

The valves, which are actuated by Joy's

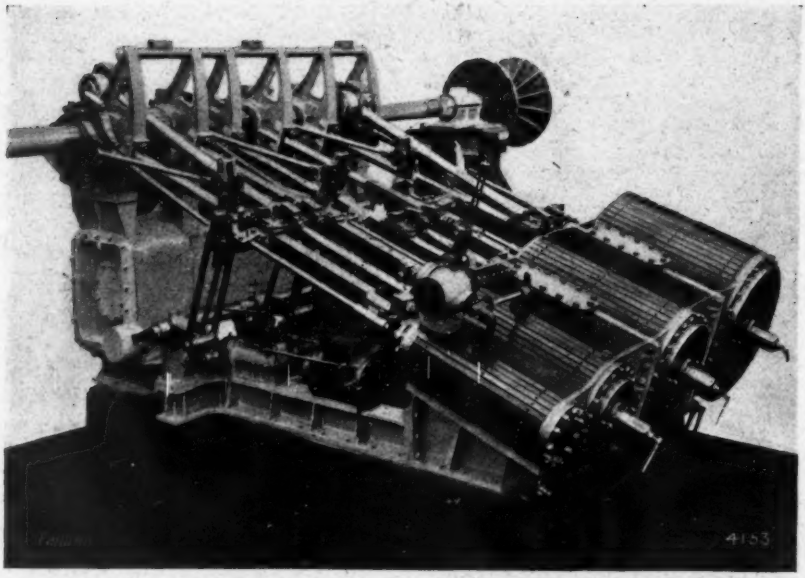


FIG. 4.—TRIPLE-EXPANSION DIAGONAL SIDE-WHEEL ENGINE.

gear, are of the ordinary D-shape and are placed above the cylinders.

The high-pressure cylinder is of 14-in. diameter, and the low-pressure cylinders 26 ins. diameter, while the stroke is 42 ins. The surface condenser has facings cast on the top to carry the pump arrangements. These pumping arrangements consist of a separate engine, which drives its shaft. To the ends of this shaft are fitted two disc cranks, and each of these cranks drives one pump.

The steam for the engines is supplied by a locomotive boiler made and designed specially for this boat. Its dimensions are 6 ft. 2 in. diameter and 11 ft. $0\frac{3}{4}$ in. in length. The engines develop 180 indicated horse-power with natural draught.

Fig. 5 shows a set of engines built for a stern paddle-wheel boat in which the machine had to be placed amidships. Long connections, some 70 ft. in length, had to be made to connect up the working pistons with the crank-shaft. The engines are of the compound tandem jet condensing type. As there could be only one crank at each end of the crank-shaft, the cylinders for each engine had to be arranged tandem, and to work the valves by an eccentric from the shaft would have necessitated the making of long valve-rods as well as long connecting-rods; so Joy's valve-gear has been fitted to get over that difficulty.

The piston-rod is made up of convenient lengths, which are connected together with flanges and bolts like line shafting. Lengths of this piston-rod are seen in the photograph to be lying on the floor of the shop. To get them to run in line with the piston-rod in the stuffing box, the lengths are supported at suitable places along the frame of the steamer, on cast-iron bearings. These bearings are bushed with brass, and are shown lying on the right of the cylinders in the photograph.

Engines of the triple-expansion type

have been largely adopted on paddle-wheel boats.

Such a set of engines develop the power for one of Messrs. Cook's Nile tourist steamers, and is shown in Fig. 4. It will be seen that the three cylinders have their centre lines in the same inclined plane with the shaft. The same type—only, of course, of greater power—are fitted by Messrs. William Denny & Co., of Dumbarton, in several of the Belle steamers. One remarkable feature of these engines, designed by Messrs. Denny, is the light, though strongly designed, cast-steel frame. At one time these frames were made of cast-iron, but when the engines were pressed hard, the frames not unfrequently broke, and by the end of the season a considerable amount of wrought-iron riveted patch-work was noticeable. Now the difficulty has been entirely overcome by making the frames of sound cast-steel.

The triple-expansion engine of Messrs. Bow, McLachlan & Co., Ltd., is surface condensing, with cylinders so arranged that the intermediate occupies the central position (Fig. 4). Each engine drives its own crank-pin, which crank-pins are set at 120 degrees to each other, so that the turning moment is very equally distributed on the shaft, which contributes to a very steady rotational movement of the paddle-wheels. The dimensions of the cylinders are, the high-pressure 16 ins. diameter, the intermediate 25 ins. diameter, and the low-pressure 39 ins. diameter, with a common stroke of 36 ins. The steam is distributed to the high-pressure cylinder by means of a piston-valve, and to the intermediate and low-pressure cylinders by means of ordinary D-slide valves. These latter valves are fitted with relief rings. The valve gear is of the ordinary link-motion type.

FIG. 5.—TANDEM COMPOUND STERN-WHEEL PADDLE ENGINES.

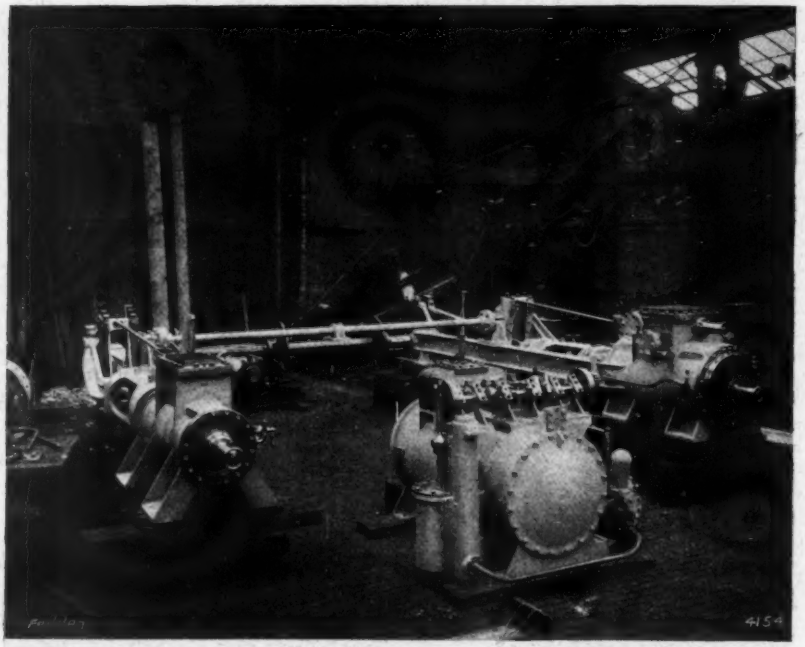


FIG. 6.—COMPOUND STERN-WHEEL ENGINES.

The engine has been designed for lightness, the draught of these Nile steamers being small. The crank-shaft is of the built-up type, and is supported on bearings bolted firmly to the shaft-framing. The surface-condenser in this case serves as a support for the shaft-framing, which arrangement contributes greatly to the lightness of the engine as a whole. Circulating water for the condenser is provided by means of a separate engine. The cylinders and condenser are connected by bed framing of cast-iron. The bearings and cylinders are tied together by means of strong forged standards, which are so shaped as to serve as guides for the piston-rod crossheads.

(To be concluded.)

Geo. Halliday

New Machinery. Appliances. Structures. & Processes.

THE MANUFACTURING WORKS OF THE BRITISH WESTINGHOUSE COMPANY.

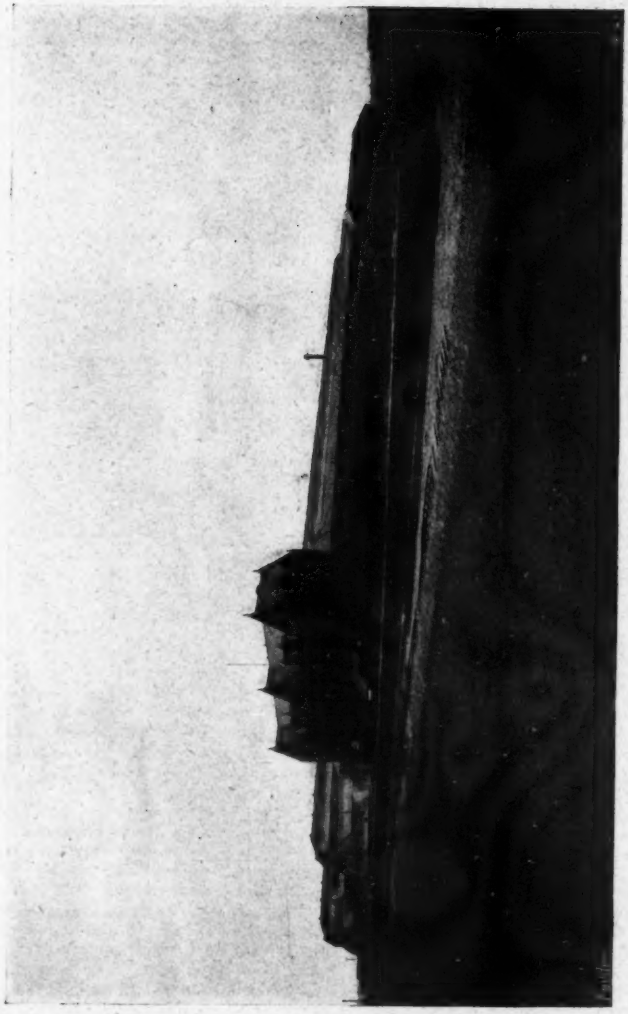
(Preliminary Article.)

THE new manufacturing works of the British Westinghouse Electric and Manufacturing Company are situated in Manchester, where they occupy about 130 acres of the Trafford Park Estate. The position of the works was only decided upon after careful consideration of several alternative districts in various parts of the country, and there can be no doubt that the best site has been secured; not only is Manchester practically in the centre of the kingdom, but it is also in direct communication with the sea; the works' site is in touch with the main line railways, the Bridgwater Canal forms a considerable length of its boundary, and the Manchester Ship Canal is in the immediate vicinity. It would be difficult to find a place better supplied with facilities for rapid and world-wide transit. Another important advantage of the Trafford Park site lay in the fact that there was sufficient and suitable land adjoining the works whereon to build homes for the employés. This land is being utilised for that purpose and a thriving model-town is already in existence.

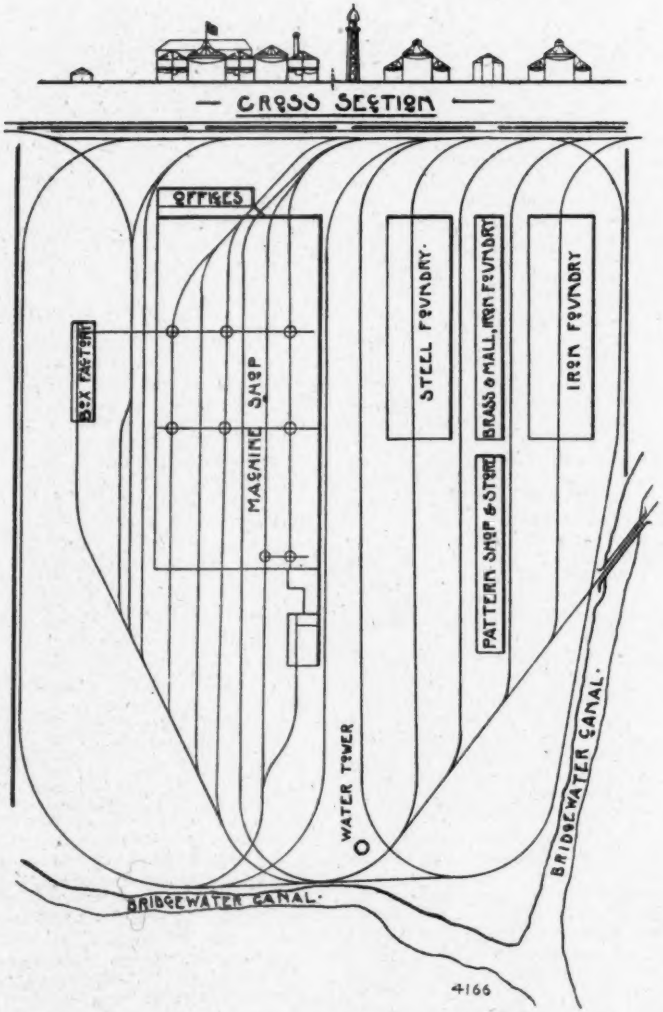
The respective positions of the nine buildings of the works are shown in the general plan (page 67); in all there are some 55 acres under cover. The shops are arranged parallel with each other, and run almost due north and south. The northern ends are brought up into line, and ample space is available for their extension in a southerly direction, as occasion may demand. It will be seen that they are arranged in the order most convenient for the progression of materials and parts, right through from the admission of raw materials at the eastern end to the output of the finished products at the western end. Two overhead crane-tracks traverse the northern end of the buildings, from the iron-foundry to the machine-shop. These outside cranes are electrically driven, and have a lift of 50 tons. Two similar but smaller-capacity cranes traverse longitudinally the space between the machine-shop and the steel-foundry. All departments are brought into direct touch with each other by a very complete network of standard-gauge railway lines, the aggregate length of which exceeds 23 miles.

All the buildings are constructed of massive steel framework bricked in. The columns are set on heavy concrete foundations, and each pair supports a roof span. The latter were supplied in halves, which were fixed together on the ground and the span raised into position in one piece. The heaviest pieces handled weighed about 25 tons, the riveting was all done with pneumatic tools, and a very rapid rate of erection was maintained, averaging about 100 tons per day.

The actual building operations commenced early last year, and building experts very freely expressed the opinion that some three to four years would be required to get the buildings up and another two years be spent in their equipment. The completed works of to-day show how mistaken they were. They had not calculated on the possibilities of modern ways and means. Mr. J. C. Stewart, a contracting engineer well-known both in this country and in America for his prowess in the carrying out of the largest building-contracts in the shortest possible time, undertook the management of the Westinghouse Works construction. He exercised his wonderful skill to an extent which more than astonished the English building trade, masters and men alike. Numerous articles have appeared from time to time in the general press regarding the apparently impossible rate at which the bricklayers were working; but the immense Westinghouse Works standing to-day where only green fields were about 12 months ago, are proof indeed that an exceptionally high rate of working must have been maintained. After the first month or so only the very best men were engaged in the work; they were paid at a higher rate than that fixed as minimum by their trade society; they worked under the most convenient circumstances; materials were constantly right to hand, and the men were ever kept at the actual working spot; in short, the most modern arrange-



GENERAL VIEW OF THE NEW WORKS OF THE BRITISH WESTINGHOUSE COMPANY, LTD., TRAFFORD PARK, MANCHESTER.



GENERAL PLAN AND CROSS SECTION OF THE NEW WORKS OF THE BRITISH WESTINGHOUSE CO., LTD.

ments were everywhere brought into use; and, what is perhaps more important than all, Mr. Stewart remained constantly in personal command. During the first month, the average number of bricks laid per man per day was about 900, but this number gradually advanced as the men grew accustomed to the unusual conditions, and the slow workers were weeded out until the average per man per day reached the striking total of 2,250 bricks. The bricklayers were the most expert that could be obtained and each man must have made a personal record. Three thousand seven hundred workmen were constantly employed, and in less than twelve months they used up over 16,000 tons of steel, 10,000,000 bricks, and 10,000,000 ft. of timber, to build works which will provide employment for some 6000 workpeople in the near future.

Every care has been given to securing the best possible hygienic conditions in every part of the works, and the lighting, heating, ventilating and general sanitary arrangements are all that could be desired. In addition to ample window-lighting, all the main shops are fitted with glazed roofs. The glass used in the roof-work is of special form, a close mesh of wire is embedded in the panes, so that in the event of breakage occurring no fall of broken glass into the shops can take place, the pieces being held together by the wires. No putty has been used for the skylights, the panes are all fixed with lead strips. Over 300,000 sq. ft. of the special wired glass has been used in glazing the roofs alone.

The heating and ventilation of the buildings are maintained by large fans working in conjunction with a very complete pipe-system. In cold weather, fresh air is drawn in, passed over steam-heated coils, and distributed from various branches and outlets of the main pipe; in warmer weather the same arrangement is used, excepting that cool, fresh air is distributed and maintained in regular circulation in all parts of the buildings. The fans for the air supply are placed immediately under the roofs of the various shops, they are all electrically driven, requiring about 40 h.p. each. The sanitary arrangements are exceptionally complete and of the most modern form, hot and cold water lavatories, private lockers, etc., are provided in each shop and department.

It would seem almost unnecessary to mention that in all departments the most modern labour-saving machinery will be used. The object sought in all cases is to produce work of the finest and most accurate finish, all parts of which are absolutely uniform in material and size, at the most rapid rate and under the most economical conditions. The transfer of materials is a very important item, and cranes, elevators, and railway tracks abound on the ground level, on the galleries and in the yards. For instance, the steel foundry contains two open-hearth 20-ton Siemens furnaces of the Wellman rolling type. The metal is hauled direct by electrical power to the charging platform from the railway, fed to the furnaces by electrical charging machines, and afterwards distributed by 50-ton overhead electric travelling cranes. The gas-producer plant and the core-drying ovens are adjacent to the furnaces.

In the machine shop, which is the largest single workshop in this country, some 1300 machine-tools are installed. These range in size from gigantic 28-ft. boring mills to toy tool grinders, weighing not more than 5 lbs. each.

This shop is arranged in five longitudinal bays or aisles, two of these are 90 ft. wide each, and are open to the roof. They are for the working of the heaviest electrical power machinery ever built, and are traversed by 50-ton electric cranes; the weight of each of these cranes is about 75 tons. The three smaller bays are divided into two floors where the manufacture of smaller machines and detail work is undertaken; they, in their turn, are traversed by many electric cranes ranging in capacity from 10 tons to 30 tons each.

Of course, electrical driving is used wherever possible; and innumerable motors, principally of the alternate-current, induction form, known as the Westinghouse Type "C" motor, are distributed throughout the various shops.

Wherever there is any possibility of an outbreak of fire, automatic sprinklers are fitted, these are supplied from a storage tank at the top of a lofty water-tower, built at the extreme south of the site. Comparatively short and incomplete as this article must necessarily be, dealing, as it does, with such a large and original manufacturing works, it ought at all events to include some mention of the office-building, which is perhaps, to the passer-by, the most prominent of the various new buildings. This is an imposing structure, six storeys high, of a neat and substantial design. It faces the main entrance of the works, being built directly against the northern end of the machine shop, with which it is directly connected on both the floor and gallery level. The offices are unusually large and lofty, and the same care of employés is in evidence here as in all departments of the works proper. The walls of the staircases and main corridors are

finished with white marble panels. The floors are all of steel and concrete fireproof construction, the ceilings being of cement keyed into terra-cotta tiles. The floors of the corridors and the halls are finished with mosaic. One part of the building is absolutely fireproof and has rooms wherein the valuable works' records, etc., will be stored. The large staff of masters, engineers, draughtsmen and clerks will occupy this building.

From this brief description, it will be gathered that no pains have been spared to make the Westinghouse Works the best possible from all points of view. They have been developed by engineers who are masters of their profession, and who, in all details, have observed strictly the requirements of modern times. One feature in this connection is particularly striking—the very obvious importance which the Westinghouse Company's advisers attach to the effective care of employés. The workman has light, clean, and healthy surroundings to work in; his manual labour is reduced to a minimum; healthy, well-built houses are provided for him; and in the way of lockers and other conveniences in the works his individuality is preserved, and he is led to be methodical, cleanly and healthy in his habits—all of which, while savouring of philanthropy, is neither more nor less than a logical and humanitarian way of increasing his efficiency as a workman and his value to his employer. It would be well, indeed, if such principles were more generally observed in manufacturing industries; the chances are all in favour of success following the Westinghouse venture, and doubtless many of the firms still maintaining old ideas and working principles will, by force of example, be led to abandon their old, expensive, and unsatisfactory ways of working, and to substitute modern systems—which certainly introduce the advantages of higher efficiency of production and better social and economic conditions for masters and servants alike.

NEW ELECTRIC RACK AND ADHESION LOCOMOTIVE.

Built for the

COMPAGNIE DU CHEMIN DE FER DE FOURVIÈRE ET OUEST-LYONNAIS, LYONS.

THE locomotive, of which illustrations are shown on page 70, has been designed and constructed by The Société Suisse of Winterthur, in conjunction with Messrs. Brown, Boveri & Co., of Baden, Switzerland, and is intended for working the steep-gradient portion of the Ouest-Lyonnais electric tramways between Lyons and the Saint-Just Plateau. The duty required of this engine is to haul a load of 28 tons on a gradient of 19 per cent. (say 1 in 5) at a speed of 2·5 m. (8 ft.) per second; and on the portions of line, above and below this gradient, where adhesion alone is relied upon, it must be able to do the shunting. The rack is on the Abt system; and the current is continuous with a tension of 500 volts.

The rack mechanism of the locomotive is brought into action by a 150-h.p. electromotor, making 700 revolutions per minute; and this motor transmits the power by means of two spur pinions, keyed on two countershafts, and engaging the spur-wheels on the two driving axles. When the engine runs with adhesion only each of the carrying axles is driven directly by a 25-horse electromotor. On the section of line laid with rack the motors for running with adhesion and with rack work simultaneously; but on the portions of line where adhesion alone is relied upon, it is only the adhesion motors which work.

The locomotive is provided with the brakes necessary for the rack and adhesion mechanisms, viz.:—

(1) Two screw-brakes, independent of one another and acting on the motive spur-wheels;
(2) A screw-brake acting on the wheels for running by adhesion; and
(3) A self-acting brake, which works on the rack section and acts on the brake-shoes of the spur-wheels when the maximum permissible speed is exceeded, or the electric current is interrupted for any reason.

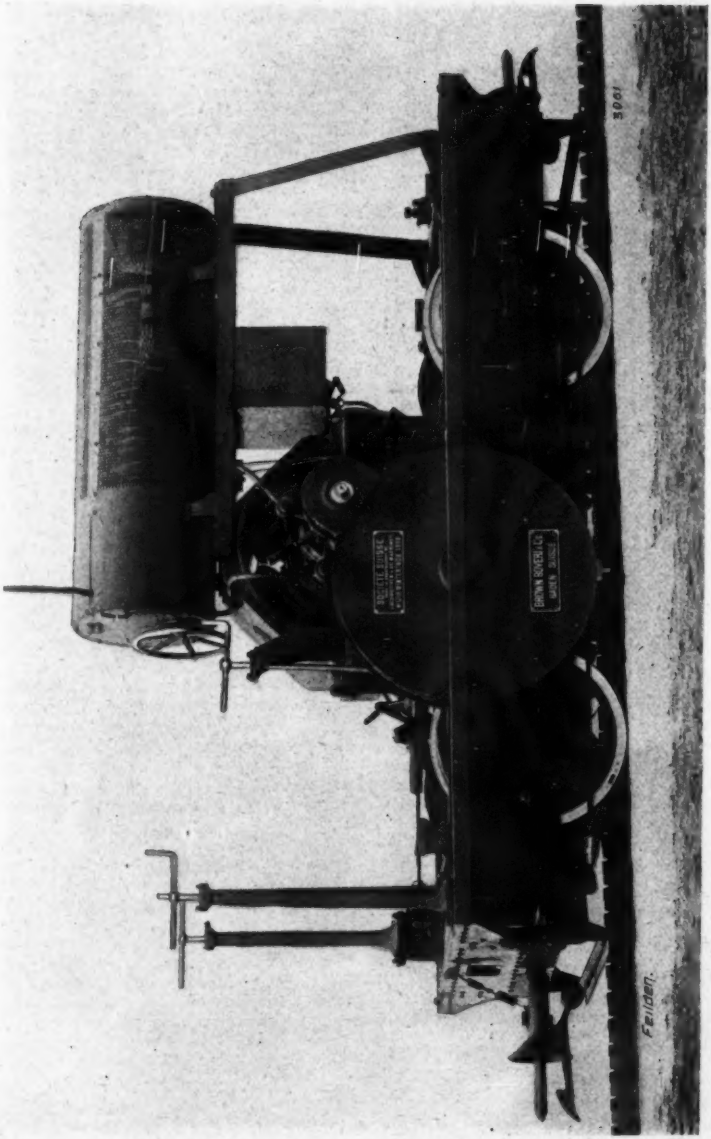
A small tank contains water for cooling the brake-shoes.

The leading dimensions of the engine are as follow:—

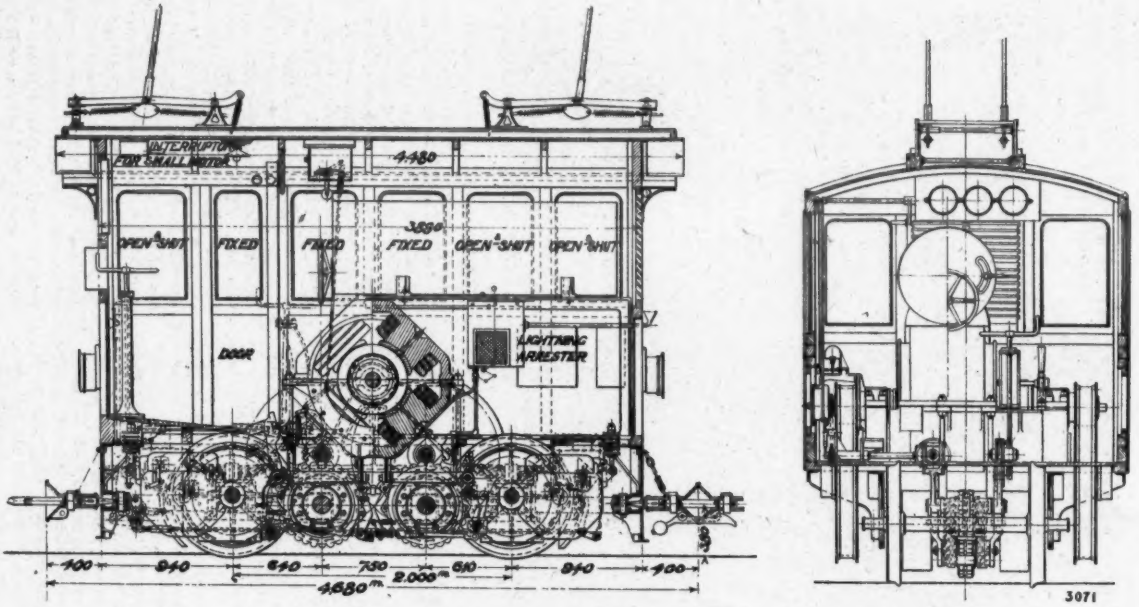
Gauge	1,000 mm. = 3 ft. $3\frac{3}{8}$-ins.
Diameter of motive toothed wheels	573 mm. = 1 ft. 10 ins.
" " adhesion wheels	850 mm. = 2 ft. 9 ins.
Speed (per hour)	9 km. = $5\frac{1}{2}$ miles
Weight of locomotive	12,000 kg. = 11·8 tons
Total weight of train	28,000 kg. = 27·5 tons
Power of rack-motor	150 h.-p.
Revolutions of rack-motor (per minute)	700
Power of adhesion motors together	50 h.-p.
Revolutions of adhesion motors (per minute)	300
Tension	500 volts.

The whole mechanism is cased in with wood, having glass panes on every side, so that the driver has a clear view of the line.

Several locomotives of similar construc-



NEW ELECTRIC RACK AND ADHESION LOCOMOTIVE



DETAILS OF THE ELECTRIC RACK AND ADHESION LOCOMOTIVE.

tion, for continuous and also triphase current, are now running, and have given very favourable results.

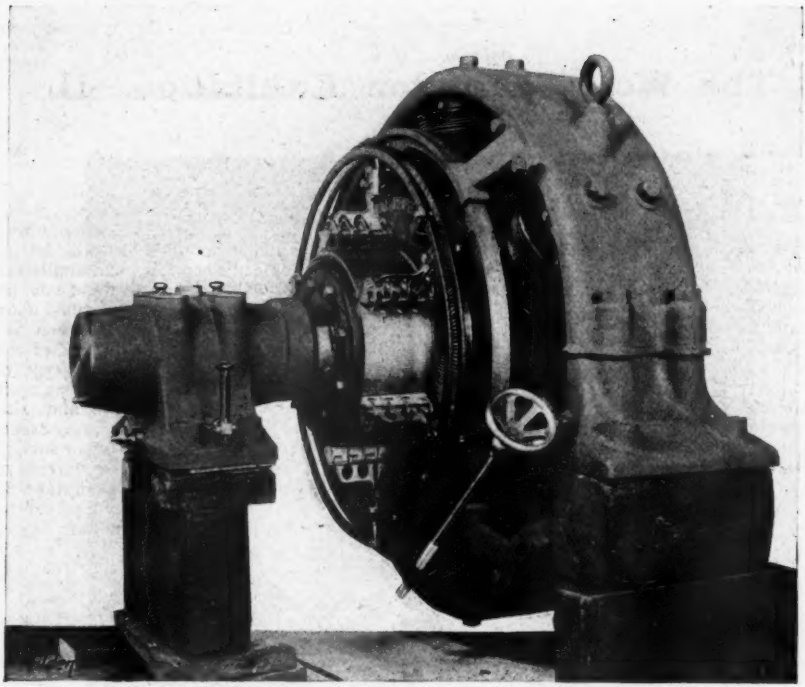
As regards the electrical equipment we may give the following particulars:—The two motors for running by adhesion are of the series wound type, generally used for tramcars, with four poles; and, as in such case, they are placed between the wheels of the vehicle. They are calculated for an output of 25 horse-power normally when making a number of revolutions corresponding with an engine speed of 9 km. (5½ miles) per hour, *i.e.*, the speed at which the engine moves on the rack. Inasmuch as the weight of the vehicle is sufficient for an effort of 25 h.-p. to be exerted on the axles without the wheels skidding, the adhesion motors may be used to add the whole of their normal power to that of the motor acting on the toothed wheels. On falling gradients these two motors revolve freely, being thrown in and out of gear by means of an ordinary controller of the parallel-series type.

The principal motor, intended to work on to the wheels gearing with the rack, is designed for 150 to 200 h.p., and is of the shunt type, making about 700 revolutions per minute. The armature consists of a toothed drum, the winding of which consists of copper bars connected in series. Owing to the great speed and the necessity for a very strong armature, instead of fastening the winding by means of cheeks, the copper bars are held in the grooves by wedges of some insulating substance. The electromotor is placed inside the locomotive; and, while the two adhesion motors are entirely cased in, it appeared necessary to leave this one uncased, in order that, notwithstanding its very small dimensions compared with the power it is capable of giving out, too high a temperature be not attained.

On falling gradients this motor acts as a generator, thus constituting a brake; and the current produced is not absorbed in the resistance coils, but is sent into the electric conductor. For rendering possible this recovery of energy there must be the faculty for sufficiently increasing the tension of the current produced by the electromotor acting as a generator, and this result is obtained by increasing the motor's excitation. In order that the inductor winding may support, without too great heating, this increase in the intensity of the exciting current, it has been divided, and between these subdivisions free spaces have been arranged that permit of active ventilation. Thanks to the circumstance that the excitation is, as mentioned above, established in shunt circuit, it is possible to pass automatically from the working as motor to that as generator, according to the gradients encountered, and this without in any way changing the connections, the speed remaining practically constant in all cases.

The starting apparatus of the motor, which is mounted upon it, permits of starting with a maximum excitation of the magnets; so that it starts under practically the same conditions as a series motor, *i.e.* with a minimum of current. Variations of speed, both on rising and on falling gradients, are obtained by varying the excitation. All the manipulations that it may be required to make with the starting apparatus are effected by means of a single hand-gear, except reversing the direction of running, which is effected by a special lever. This latter is connected with the hand-gear in such a manner that it is impossible for the driver to make a mistake. The current is taken off by means of two bows, on account of the great intensities required by the locomotive, and also for insuring a more regular taking off of the current. Thanks to their special construction, these bows can work in any position between vertical and horizontal, this facility being necessitated by the great differences in height presented by the contact wires on the Lyons-Fourvière railway. In the tunnels of this line the contact wire is hung at only a very slight distance from the carriage roof, while in all other parts of the line it is 6 metres (19 ft.) above the rails.

Lastly, the electric equipment comprises a certain number of appliances and instruments for ensuring the good working and safety of the exploitation; and they consist of lightning conductors, fusible cut-outs, measuring instruments (voltmeters and ammeters) that permit of keeping a check on the current passing into the motors, a solenoid with soft-iron core, a safefy interrupter for the motor circuit when the engine is running by adhesion, and another for that when it is running on the rack. The part played by these three last-named appliances is the following: if, owing to any accidental cause, the current should not reach the locomotive, the solenoid, being no longer excited, will let fall its soft-iron core, which will throw into gear the mechanism for applying the safety brakes, and thus pull up the train. At the same time the fall of the soft-iron core will bring into action the safety interrupters; so that, in case the current should return suddenly, it cannot reach the motors when once the brakes are put on.



ENGINE TYPE GENERATOR.

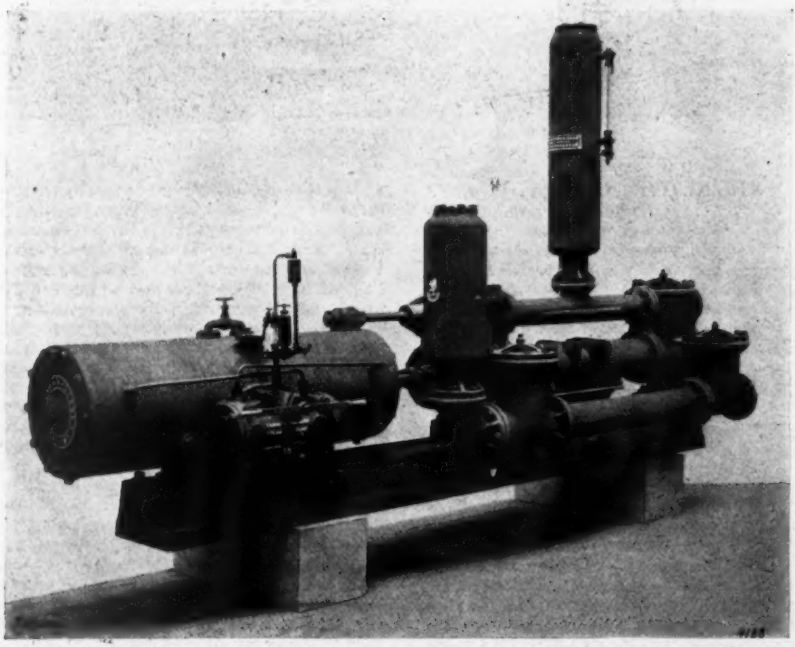
ENGINE TYPE GENERATOR.

THE illustration herewith, represents Messrs. Ernest Scott and Mountain's latest type of generator for direct coupling to high speed or slow speed engines ; this type of generator being constructed in all sizes. On reference to the design, it will be noted that the armature is of the slotted drum type, with former wound embedded conductors, the conductors being laid in the slots after being carefully insulated. The core is composed of steel plates of high magnetic permeability, mounted upon a cast-iron centre with driving slots ; cast-iron cramping plates are fitted at each side, which not only keep the core-plate in position, but carry the ends of the armature conductors. The commutator is of hard drawn copper insulated with mica, and bolted direct to the armature core, so that the whole is positively driven, and the spindle can be removed if required. The magnet frame is of steel with internal poles, and this type of machine is made with four poles in the small sizes, up to 16 poles in the larger sizes. The poles are cast separate from the yoke, so that they can be withdrawn side-ways, and the magnet coils removed if required, the poles being secured to the yoke by turned steel bolts. The magnet frame is in halves, so that the top half can be removed from the armature. The brush-gear is supported by brackets bolted to the yoke, and the ring supporting the brush-holders revolves in these brackets by means of a screw and hand wheel. The brush-holders are of special design to take carbon block-brushes, and each are fitted with tension-springs, to vary the tension of the carbon block on the surface of the commutator, and also with vertical movement, so that any wear of the commutator can be taken up. These generators are designed so that the temperature rise after a run for six hours at full load, will not exceed the temperature of the surrounding atmosphere by more than 70 degs. Fahr., and the machines are capable of withstanding an overload of 25 per cent. for two hours, or a temporary overload of 50 per cent. for short periods, without adjustment of brushes.

The Wolverhampton Exhibition.—II.

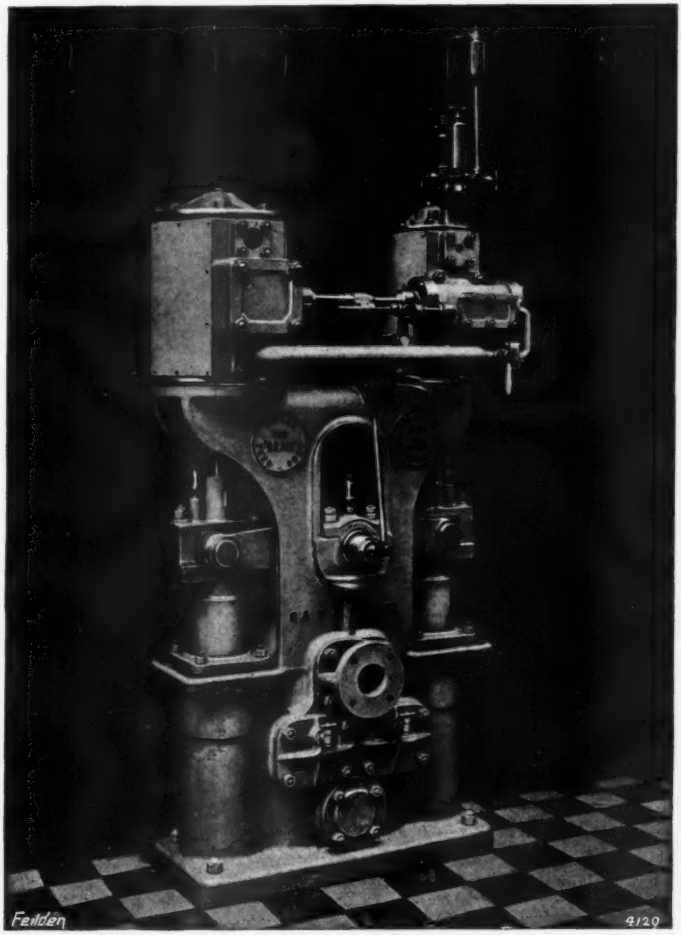
Messrs. Joseph Evans & Sons.

This firm provide a battery of feed pumps for supplying the feed water to the main range of boilers. These pumps are fixed in an extension of the boiler house, and draw their water from a storage tank, which latter is supplied from the Corporation mains. The steam pressure carried on the main boilers is 180 lbs. per square inch, and the discharge water passes through a relief valve loaded to 200 lbs. per square inch pressure when not required in the boilers. There are three separate pumps, all of which are on the compound principle; two are of the horizontal type, and are fitted with the patent "Cornish" system of compound steam cylinders and double-acting outside-packed-ram pump ends. The steam cylinders are 9 ins. and 16 ins. diameter respectively high and low pressure, the rams being $7\frac{1}{2}$ ins. diameter, all 24-in. stroke. Each of these two pumps, at moderate speed, will deliver 8,000 gals. of feed water per hour, and either of them is capable of taking the maximum load duty that the boilers will be called upon to perform. They can be run as slow as two piston feet per minute. The valves in the pump end are of the "double-beat" type, of gun metal, with flat faces, and each pump is provided with large air vessel, and also vacuum chamber, so as to obviate any excessive shock, either on the delivery or suction sides of the pump; in fact, the working of these pumps is so smooth that, when standing by, no vibration or noise of any kind can be perceived. The steam cylinders are lagged



MESSRS. JOSEPH EVANS AND CO.'S "CORNISH" STEAM PUMP AT THE WOLVERHAMPTON EXHIBITION.

SUP



NEW VERTICAL COMPOUND "BEAM" FEED PUMP.

By Messrs. JOSEPH EVANS & SONS, Wolverhampton.

with sheet steel secured with brass bands, giving a very neat and well-finished appearance.

In addition to the two pumps already described above, Messrs. Evans & Sons provide an entirely new type of pump, namely, a vertical compound "Beam" feed pump, having 6 ins. diameter high-pressure and 10ins. diameter low-pressure steam cylinders, two 6 ins. diameter single-acting rams, all 12-in. stroke. This latter pump, which possesses some novel features in the valve motion and general arrangement, etc., is capable of delivering about 3,500 gals. of water per hour to boilers, and is calculated to deal with the ordinary day load on the boilers. This pump has been specially designed to meet the exigencies of boiler feeding at high pressure.

It is well known that the fly-wheel type of pump, with vertical outside-packed single-acting rams, is the most efficient and reliable type of feed pump for moderate pressures of steam and for regular work. Whilst the double-ram fly-wheel type of pump is satisfactory to a certain extent, the latter has the disadvantage of not being able to run at sufficiently slow speed with reliability to meet the varying conditions of boiler feeding, where frequently the demand varies from the maximum to almost nil within a very short time. Furthermore, the length of stroke that can be given with the fly-wheel type of pump is limited; since, in order to get any length of stroke, the vertical height of the pump itself would be increased beyond reasonable limits.

In the "Beam" feed pump illustrated in the frontispiece, the crank motion and fly-wheel are dispensed with, but the same general arrangement of steam cylinders and rams is maintained; the two sides, however, are coupled together by means of a steel beam vibrating on a central shaft. Each pump-ram has a crosshead and slide arrangement, enabling the radial motion of the beam to accommodate itself, the actual travel of the slipper block however being very small; for a 12-in stroke of ram it is about 1 in. only.

The high-pressure steam cylinder is placed over one ram, and the low-pressure cylinder over the other; the steam valve motion is driven by means of a small crank on the end of the beam shaft, connected up by means of a rod to a small "L" lever, mounted on a suitable bracket. This latter lever, in its travel, moves over a small auxiliary valve working in the high-pressure steam chest, and so admits steam to either end (as the case may be) of a piston working in a small supplementary cylinder. This piston is attached by means of suitable spindles to both the high-pressure and low-pressure slide valves, so that, when it is driven over by the steam, it reverses the slide valves of both steam cylinders simultaneously.

The auxiliary valve mentioned above is also a small slide-valve of very simple construction, and is so arranged that it uncovers its ports at the extreme end of its travel only, consequently, the liability to vary in the stroke, common to most direct-acting pumps, is eliminated, and the working speed of this pump can be regulated down to a mere crawl, with absolute certainty of running satisfactorily under all circumstances.

Messrs. Evans & Sons also provide the whole of the pipes, valves and connections for the installation of these pumps, the arrangement being such that any pump may work independently of the others, or the whole of them simultaneously if required.

Workshop Practice

Practical suggestions for this section are invited, which, if accepted, will be suitably paid for. Wherever possible, drawings should accompany the contribution; rough sketches will suffice. Nothing will be too poor for a careful inspection. See important announcement in advertisement pages.

❀ ❀ ❀

Notes on the Design of Trolley Wires and Feeders.—It is repeatedly stated that it is unusual to take into account the trolley wire itself, when designing the feeders of a tramway system, and for the following reason :—Should a section of a single unfed trolley wire break down, the whole of the traffic beyond the break would be stopped. A single trolley wire is, however, quite an exceptional case. With two trolley wires, a break in one wire does not suspend the whole of the traffic, as it does with the single trolley wire.

Copper is in its most economical position in the trolley wire, as it is cheapest there, and is easiest to erect and maintain in that position than underground, a fault being more quickly located and removed in a trolley wire than in one that is out of sight.

The usual sizes of trolley wires are Nos. 0000, 000, and 00S.W.G. Take No. 0000 and calculate the maximum length of line that can be worked, with an average service, without feeders, assuming the usual drop of 50 volts in the line. The cross section of No. 0000 is .125 sq. in. and as there are two wires in parallel, the total cross section is .25 sq. in. Assume that the trolley wires of this section are fed only at the commencement of the lines, and that the cars run at the specified limit of 8 miles an hour, that there is a five-minute service, and that each car takes 20 amps.

The usual speed is nearer 12 miles an hour than 8 miles, but a special license is required for speeds higher than 8 miles. The above figures are all on the right side. One town runs its cars for an average current of 9 amps. per car. A ten-minute service would also be more like the actual practice, except in the dinner hour, and in special cases. Uphill also, cars take more than the average, but it is made up by the smaller current taken on the levels, and on down grades. In tramway stations in which the writer has been employed, where the route has included steep hills and level roads, the average current has always been about the same, with a given number of cars on the road.

And this seems reasonable, as it requires eight times the power to drive a four-wheeled car, with a 6 ft. 6 in. wheel base, and 16 ft. long inside the car up a hill having an inclination of one in ten, that is required to drive it at the same speed on the level. On the level it will require 5 h.p. and a horizontal effort of 250 lbs. will be required to maintain this speed, and two 30 h.p. motors will take 49 amps. to produce this effort. On a grade of one in ten the same motors will exert an effort of 2,000 lbs. with 119 amps.; or roughly twice to three times the current. The cars usually slow up a little going up hill, though on a lesser gradient it is not so noticeable. If the descending car is able to return energy to the line it is helping, as usual it reduces the average current. The above figures are from Dawson's Pocket Book.

En passant, it may be remarked that braking by returning energy to the line has the disadvantage that if the trolley leaves the wire the brake is taken off, the car having to rely entirely on the hand brake, and disaster sometimes following. This does not apply to the Electric brake where the motor runs on its own field, through a rheostat, operating as a generator for the time being.

Assuming a car to have been running five minutes, after starting from the feeding point, and the returning cars to be midway between the outgoing cars, the cars are $\frac{1}{4}$, $\frac{3}{4}$, $1\frac{1}{4}$ miles from the feeding point respectively. That

is, they are spaced evenly along the line at intervals of $\frac{1}{3}$ of a mile apart. The resistance of $\frac{1}{3}$ of a mile of copper .25 sq. in. in section is ·06 ohm. In this, and the calculations which follow, the values have been worked out with the slide rule, so are to be taken as approximate.

Call r the resistance of the length of trolley wire between two cars.

Call c the current taken by each car.

Then the total drop in pressure to the nth. car is,

$$Pt = rcn + rc(n-1) + rc(n-2) \ldots + rc.$$

This is an arithmetical progression, and its sum is—$P_t = rc(n+1)\frac{n}{2}$

Putting the values given above for P_t, c, and r, we find—

$$50 = \cdot 111 + 20(n+1)\frac{n}{2}$$

$$n^2 + n - 45 = 0, \quad n = 6 \cdot 275$$

As in this case n is a third of a mile, the result means that $\frac{6 \cdot 275}{3}$, or two miles, could be run unfed under the above conditions. That is to say, a short route of two miles, running only six cars, need only to be fed at one point, if the full 500 volts are maintained at that point. If the power house is in the centre of the route, four miles, running a maximum of 12 cars could be run, fed only from the centre. If the route extends for more than two miles on either side of the power house, it will require to be fed for some part of the way, and the best size of feeder having been found by Kelvin's law, the drop in pressure may be found from the following formula.

$$P_t = [r(n+1)n + r_1(n+1)n_1 + r_2(n+1)n_2 + \ldots]\frac{c}{2}$$

Where P_t and c have the same meaning as above, and r equals the combined resistance of feeder and trolley wires for the first length of feeder, running n cars, r_1, r_2, the same for second and third lengths. The permissible length of unfed feeder will therefore be shorter, the farther it is from the first feeding point, going outwards from the power house.

The fact that when one trolley wire breaks down, the other has to carry all the current, causing a large drop of pressure at the end of the line, and injuring the line itself, if it is near the feeding point, is against the use of unfed trolley wires; but taking the case of the six cars in two miles, the total current would be 120 amps., or a current density of 960 amps. per sq. in. which is perfectly safe. The larger the trolley wires are, the greater is this effect.

As to the advantages of using a stronger trolley wire, of higher resistance, there is much to be said, when the route is a long one; but if the route is not over two miles in length, from the first feeding point, the advantage seems a doubtful one. Take as an example, Phono-Electric wire. The makers claim that little increase of *total working resistance* results. This is quite correct, from their point of view. For, taking as they do, the e. m. f. of the motor as equal to a resistance, it is clear that the greatest amount of energy must be expended there, for economical working, and the smallest possible in the trolley wire.

In other words, the percentage of the total resistance borne by the trolley wire must be small, so that an increase of trolley-wire resistance can only be a small percentage of the whole resistance. It can be shown, however, that it materially affects the drop of pressure in the trolley wire.

Taking the first example, of two unfed trolley wires, and doubling the resistance of the wires, we get for the maximum distance:

$$50 = \cdot 222 \times 20(n+1)\frac{n}{2}$$

$$n^2 + n - 22 = 0$$

$$n = 4 \cdot 1$$

Or slightly more than $1\frac{1}{3}$ miles can be fed at one end, and only 2.7 miles from the centre. And as suburban routes of two miles each are very frequent in moderate sized towns, while routes of one mile hardly take one out of the business portion of the town, it will be seen that this forms a great objection to the use of high resistance wires for trolley work. On a long route with heavy feeders, the objection disappears, because the feeders are very large compared with the trolley wires.

If the ratio of the resistance of copper trolley wire to phono-electric wire of same size = l, and the ratio of the resistance of the cables to the resistance of the copper trolley wires = m.

Then for the same drop, load, and length of line, the higher resistance wire must have a cross section = $\frac{1}{l}$ of cross section of copper wires without feeders If there are feeders, then the cross section of the copper in the cable must be increased by an area $\frac{l}{m}$. In phono-electric wire, $l = \frac{1}{2}$ roughly, so that without feeders, the replacing of copper wires by phono-electric would necessitate a phono-electric wire of twice the size to maintain the same conditions. This is impossible, so it would mean laying a cable for some part of the way. With feeders, the extra cross section would be $\frac{m}{2}$. If there is a long line with heavy traffic, m will be very small, so

that the cost of extra copper would be negligeable.

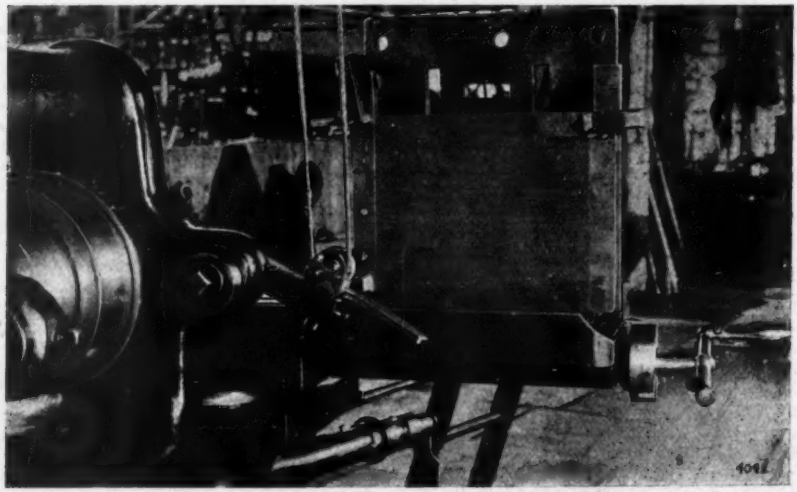
To sum up, it seems to the writer that there are many routes, for a distance of two miles from a town, that might be run without feeders, with just as great security against break-down, as with a light feeder, say a 1.05 running alongside them, and with no more than a comfortable drop of pressure; that it is advisable to make the trolley wires as large as practically possible; and that it is best to run a short length of feeder, and keep as much as possible unfed, than to run a thin feeder the whole distance. Also, that in the centre of a busy town, where the cables are large compared to the trolley wire, and the traffic heavy, and the danger to the public of a broken wire is serious, it is advisable to use a tougher metal than copper, but where the traffic is on country roads, copper is best.

(Prize) "ASSISTANT"

A Milling Machine Job.—As illustrating the diversity of work which may be done on a milling machine, the drilling of 7,000 holes $\frac{1}{16}$ in. in diameter, $\frac{1}{8}$-in. pitch serves as a very good example. This was accomplished by clamping the plate to be drilled to the face of an angle-plate bolted down to the table of the machine, and interposing a strip of steel about $\frac{1}{2}$ in. thick between the plates at each end, to allow clearance for the drill. The plate in question was 12 ins. long by 9 ins. wide, the area to be drilled 10 ins. by 7 ins., and the method of procedure as follows. The table was lowered in its vertical movement to the bottom. The indication-plate on the vertical spindle being graduated to read in $\frac{1}{100}$ was raised $\frac{1}{100}$ for each row of holes to be drilled. By commencing on the top row first and lifting the table up, all the back lash of the gears was, in raising, kept in hand; care being taken in not lifting the table more than $\frac{1}{100}$ each lift. The longitudinal slide was graduated in $\frac{1}{8}$ths, thereby necessitating moving the table $\frac{1}{8}$ths each time. The drill was fixed in the back-gear spindle-socket. The plate was first centred by just piercing so as to make a start for the drill (to avoid its running out of its course), afterwards being drilled through. By looking closely at the illustration it will be seen how accurate the plate was when finished.

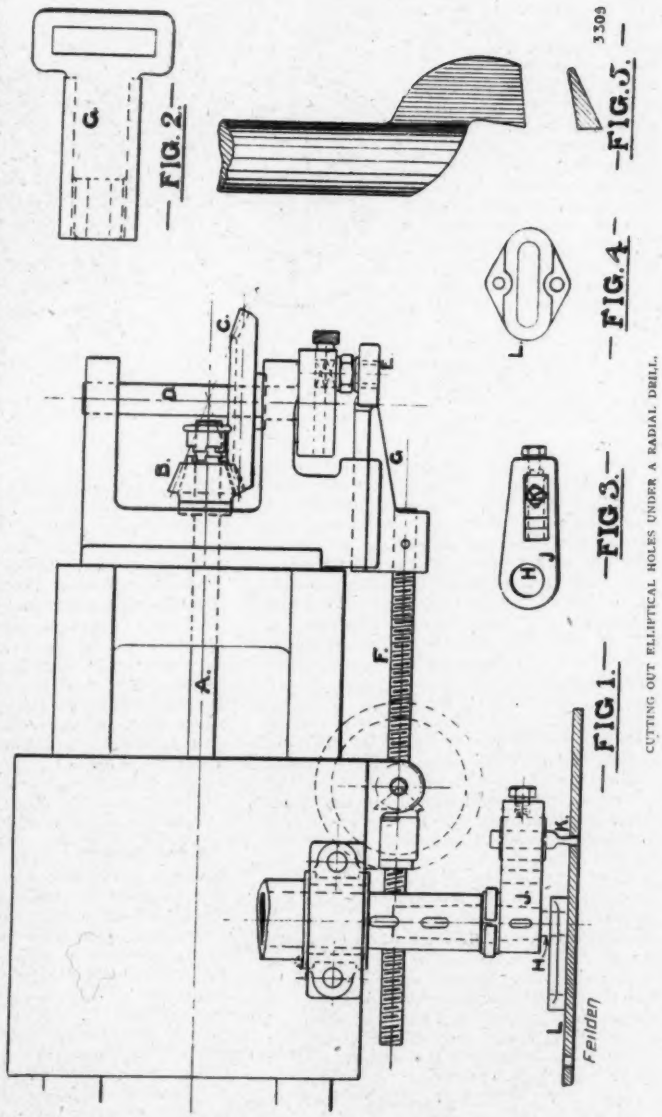
(5.) E. A. HOLDSWORTH.

Cutting out Elliptical Holes under a Radial Drill.—It frequently happens in boiler and other shops, that elliptical holes are required to be cut through plates, etc., and the usual process is to mark out on the plate and drill a series of holes round the inside of the circumference, then chip and file away the projections left between them. This is a



A MILLING MACHINE JOB.

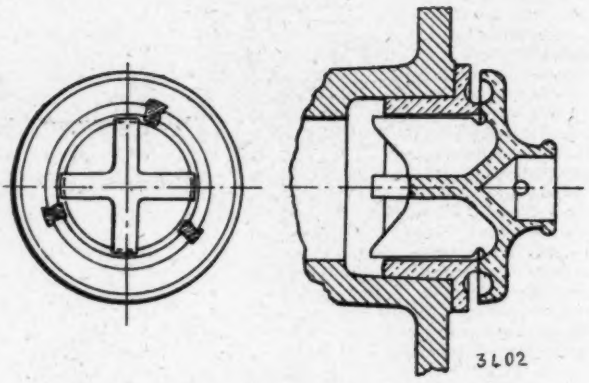
somewhat tedious process, without satisfactory results, and, to meet the demand for a rapid and more accurate method of producing this form of hole, the following attachments to a radial drill were devised. The splined shaft *A* (Fig. 1), which traverses the length of the arm, was lengthened beyond the arm to carry the bevel pinion *B*, which gears into the wheel *C*, keyed on the vertical shaft *D*, and the ratio of *B* to *C* is *exactly* the same as the ratio of the gearing between the shaft *A* and the drill spindle, so that shaft *D* makes one revolution for each revolution of the spindle. The bottom end of shaft *D* carries a disc, with a T-slot in it, along which the pin *E* can be adjusted by means of a screw. The amount of traverse given to the pin *E* determines the maximum amount of difference between the major and minor axes of the elliptical holes to be cut. The pin *E* works the saddle backwards and forwards by means of the screw *F*, one end of which is free, and the other pinned to a guiding frame *G*, having a cross-slot, as Fig. 2 for the square die on end of pin *E* to work in. The saddle can be moved to any desired position along the screw by revolving the cylindrical brass nut, supplied with mitres and handwheel for this purpose. Into the end of the spindle is cottered an arbor *H*, to which is attached an arm *J*, carrying the cutting tool *K*. The nut shown between the



CUTTING OUT ELLIPTICAL HOLES UNDER A RADIAL DRILL.

spindle end and arm serves the double purpose of forcing the arbor *H* out of the spindle, or forcing the arm *J* off the arbor. The parting tool *K* (Fig. 5) is of circular section steel, 1 in. diameter, and its cutting edge is cranked back, behind the abutment, against which the tool presses; so that any spring it may have, because of its somewhat attenuated section, will cause it to spring away from the work, and not to dig in. The slot in the arm *J* (Fig. 3) is not radial, but so arranged that the edge of the cuttting tool *K* is always radial when shifted along the slot. If the sleeve from which the machine arm projects is held from rotating by means of a worm and worm-wheel—gearing without any backlash—the apparatus already described would be sufficient for cutting out the elliptical holes, but the machine under consideration had no such locking arrangement, and the guide *L* was required to carry the end of the arbor *H*, the amount of travel along the slot (Fig. 4) being equal to the difference between the major and minor axes of the ellipse. The method of using the apparatus is as follows. The pinion *B* is disconnected from the clutch on the shaft *A*, and using the machine as for ordinary drilling, two holes, with their centres on the minor axis and equidistant from the major axis, are drilled and tapped. Then pinion *B* is clutched to shaft *A*, the arbor *H* carrying the tool *K* inserted into the spindle, and the guide *L* screwed down in proper position. The end of the arbor is adjusted into the centre of the guide-slot, and the proper amount of eccentricity obtained by adjusting the pin *E*. The maximum size of hole cut by this apparatus is about 10½ ins. by 14 ins., and the greatest eccentricity is 3½ ins. The maximum thickness of plate to be operated upon is ½ in., the cutting edge of the tool is about ¼ in. wide, and the spindle feed is about ·04 in. per revolution.

(6.) JOBIC.

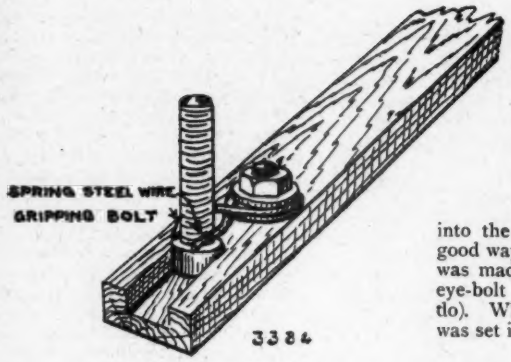


TRUEING VALVE SEATS IN POSITION.

Trueing Valve Seats in Position.—It is frequently the case in repairing valves having flat seatings, that the latter are found badly "pitted," and in order to make a proper job, these holes should be ground out. This often occupies a great deal of time, consequent upon the slow cutting of the emery which is generally employed for the purpose. A far more effective method is to attach, by means of solder, three short pieces of shot file, about ·10 thick, to the valve, as shown in the sketch, then by revolving the latter in the seating, at the same time exerting a little pressure, a very satisfactory job can be made. After the use of the valve for this purpose, the pieces of file are removed by heating, the valve is then ground to a fit with flour of emery in the usual manner.

(3.) H. O. DIXON.

A Bolt Support.—In many instances some difficulty is experienced in getting a bolt in position from the inside of a job, such as a machine base or bed, where the bolt holes have been drilled from the outside for standards, brackets, etc., or in the case of boiler mountings having nuts on the outside. An ingenious device is shown at Fig. 1 for supporting a bolt until it is located, and it may be further utilised for other purposes. It consists of a suitable piece of timber, with a recess at the end to receive the head of the bolt; a small stud secures a piece of spring wire shaped to grip the neck as shown. By this means the bolt is held in a vertical position, and may then be inserted in the hole and held in place until the nut can be threaded; it is then readily withdrawn, and has the



A BOLT SUPPORT.

advantage of being easily made and accommodated to any size of bolt.

(3.) PRACTICAL.

[We think this an improvement over the old method of hauling a bolt through with a piece of cord.—ED.]

A Flange Wrench.—The illustration shows an improvised form of spanner or wrench, used for screwing up the gland-shaped flanges on copper and other pipes. It consists of a piece of 1-in. timber about 4 ins. wide and of a convenient length, with pieces fastened at the required distance with three or four wood screws. It has been found a useful and inexpensive addition to the pipe-fitting shop, the strips being easily altered to suit any size of flange. It further saves the damage sometimes done to the flange bolt-holes by inserting studs and using them—with a bar across—for screwing on the flanges.

(3.) ANDREW A. MCNEILL.

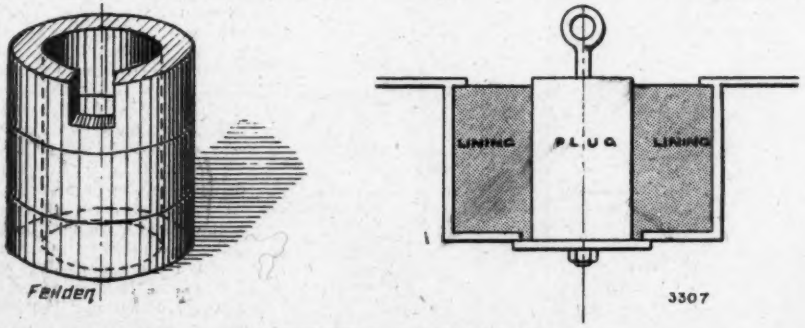
A new method of repairing Brass Furnaces. — The rebuilding or relining of brass furnaces is not the big job it once was. Most of the up-to-date foundries have "Caisson furnaces" which only require relining occasionally. Some firms, instead of using bricks and a bricklayer for this purpose, get fire-clay liners, Fig. 1, made in one piece, to slip into the casing. But an idea struck us as a good way of using up old material. A plug was made with a hole through it to allow an eye-bolt to pass (an old liner pattern would do). When the casing was stripped this was set in position, and a plate large enough

A FLANGE WRENCH.

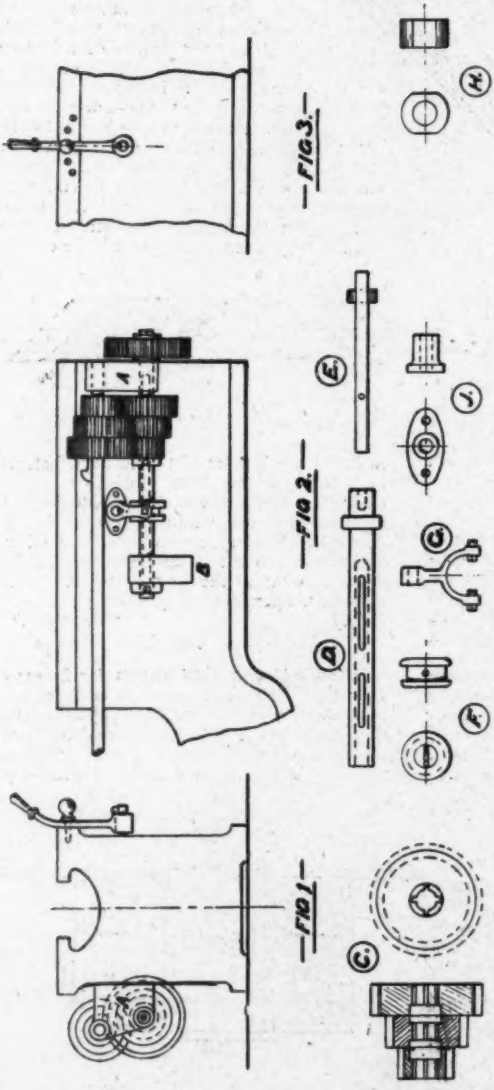
to cover the bottom of the furnace fastened to it from below. The space between the casing and the plug was then filled up with a mixture of fireclay and broken firebricks, made like concrete; this was rammed up and allowed to set. The result was a lining equal in wear to the best firebrick. Fig. 2 shows the operation completed.

(4.) "BRASSEY."

A Quick-Change Feed-Motion for Lathes.—Few modern improvements, if any, have done more to increase the output of the lathe than the quick-change feed-motion, and any lathe without this valuable acquisition may be considered obsolete, and the productive power



NEW METHOD OF REPAIRING BRASS FURNACES.



QUICK-CHANGE FEED-MOTION FOR LATHES.

of the same much below up-to-date workshop practice. Having a number of good 12-in. lathes, in every respect modern, but without this cost-reducing improvement, we decided to fix the attachment to each one, and, composed of the following details, added with only slight alterations to the existing arrangement. Fig. 1 shows end view of lathe-bed with new bracket *A*, carrying the ordinary back-shaft and short shaft for change gear wheels, a bracket *B* supporting the other end as shown at Fig. 2, together with the general arrangement of change feed gears and sliding collars, operated by forked clutch lever. Fig. 3 shows change gear lever. Three pairs of new gears were required for each lathe of 20T., 30T. and 40T., these giving a traverse of $\frac{1}{16}$-in., $\frac{1}{12}$-in. and $\frac{1}{8}$-in. with suitable driving gear. The three gears on the original back-shaft are keyed fast, the other three on the driving being loose, but provided with keyways to engage with the sliding driving key. Both keys and keyways should be well rounded off, in order that an easy entrance may be effected whilst the lathe is running. The centre gear is recessed at both ends, and the two outside ones on their insides only, the spaces being large enough to allow the driving-key to freely revolve when the back-shaft is disengaged. A section of the gears at *C* shows how they are bored and the keyways cut. The hollow shaft marked *D*, which carries the gears, is bored out about $\frac{3}{4}$ of its length, and allows the sliding spindle *E*, into which is fitted the driving key, to be an easy fit. Two slot holes are cut in the hollow shaft, one to allow the driving key to pass through when engaging with the gears, the other, for the passage of a round pin holding the sliding collar *F* on the spindle. This collar is moved

by the forked lever *G* having pins screwed in the ends which support the brass blocks *H* with milled flats fitting the groove in the sliding collar and preventing any backlash. A shaft, supported by flanged bushes *J*, passes through the lathe-bed, and on this is keyed the fork lever at the back, with the shifting lever at the front, and provided with a movable pin which may be pushed into any one of the five holes provided for the purpose of locking the lever in any position relative to the keyways and recesses in the composite pinion *C*. When the lever is perpendicular the middle feed gear is engaged, the next hole on each side stops the gear altogether, and the two outside holes each engage the fastest and slowest feeds respectively; the lever handle is curved outwards at the top, to allow the hand of the operator to be clear of the headstock, etc. The time saved by this motion, especially when feeds require changing often for roughing and finishing cuts, is enormous, as it is done instantly without stopping the lathe and finding loose change gears, etc., for the back-shaft. The driving wheel is keyed on the end of the hollow shaft instead of the back shaft as before, and is driven in the usual way by a large intermediate wheel on the quadrant. The whole arrangement worked very satisfactorily, and quite equal to any other lathe which had the motion fitted when new; great care should be taken to lubricate the three wheels which run loose on the short back shaft; grooves should be cut down on their sides for this purpose.

J. GREEN.

(6.)

A Milling Device.—*A* in Fig. 1 is an iron plate, which has a hole bored through at *B* to admit the bush of a circular platform or flange *C* (made of any suitable metal). The bush is so fitted that the platform or flange is free to revolve, it having a hole in the centre to admit the bolt; holes are also drilled round the flange, as shown at *a*, *b*, *c*, *d*, *e* and *f*, at equal distances apart. When the flange is revolved so that one of the holes comes under the milled head-screw *D*, which is fitted to cock *E* (see Figs. 1 and 2), the point of the screw will enter the hole when it is screwed down, and thus hold the flange firmly until a cut has been taken off one side of the hexagon by a revolving cutter of suitable shape, fixed in a chuck or the centre hole of the head. After one side has been done, the flange is released and moved round to the next hole, and so on until all

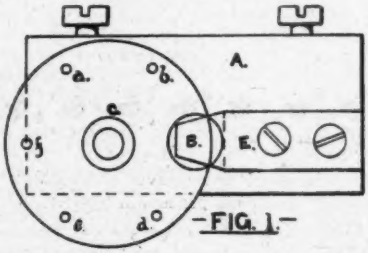


FIG. 1.

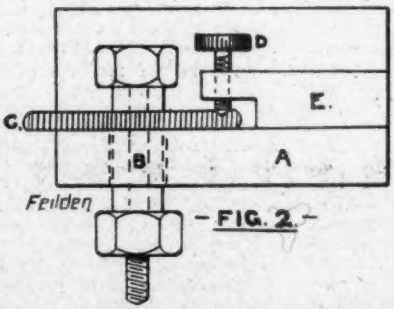


FIG. 2.

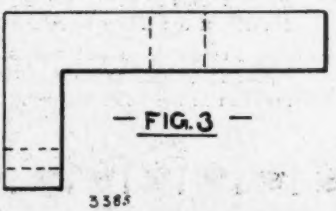
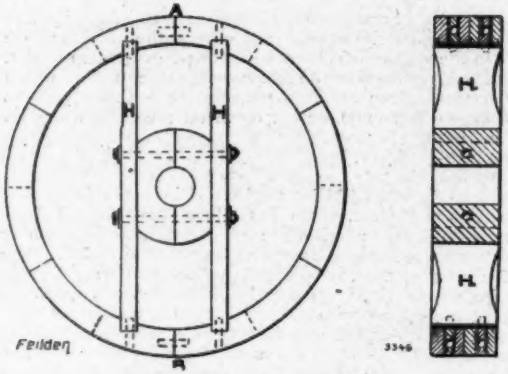


FIG. 3

A MILLING DEVICE.



MAKING A WOODEN SPLIT PULLEY.

the sides have been done. Fig. 2 shows the bolt in position ready to be operated upon. It will also be seen that the nut can be machined in the same way by simply reversing the bolt, thus bringing the nut into line with the cutter.

(4.) W. G. WAGGOTT.

Making a Wooden Split Pulley.—Having to fix a new fan in our works, we required for driving the same a large split pulley of 4 ft. 6 ins. diameter and about 5 ins. wide, which we built up out of some rough timber, as follows. We first marked out a segment templet one-sixth of a circle, and this we used for marking out the whole of the segments required in building up the rim. The segments were sawn out, faced up, glued and nailed, the joints crossing one another as the building up proceeded. The arms *H H* were housed and dowelled into the rim, and two pieces of timber inserted between them to form the boss. The rim was then sawn through at *A B*, the halves being bolted together on the shaft and turned up in position, no key being necessary, the pulley gripping the shaft lightly.

(3.) J. SEABOURNE.

AS a further inducement to our Artizan readers, and an additional subject of interest, we have decided to assign one page per month to questions bearing on the Workshop and Practice therein.

A query, if deemed suitable, will be inserted and paid for, together with what is considered by the Editor to be the best reply to the same. The decision of the Editor to be final.

The questions and replies should be written on one side of the paper only and should arrive not later than the *second* week in the month for insertion in the following month's issue.

Engineering Notes From all Sources

❀ ❀ ❀

Twentieth Century Locomotives.

Mr. C. Rous-Marten, in a recent paper on this subject, read before the Society of Engineers, pointed out that a large proportion of the locomotives employed on British railways were 20 years old and upwards, many were from 30 to 40 years, and some were still older. British engines only 20 years old are regarded as comparatively modern, whereas 20 years old American locomotives are deemed utterly archaic. Some of those elderly British engines did most important work on the leading railways of the Kingdom, having been repaired, renewed and rebuilt, until they were virtually new machines, but necessarily deficient in the power demanded by the requirements of modern traffic. Hence on certain lines piloting was carried to wasteful excess. In other instances the loads for the older engines were limited to five-sixths of that given to modern engines. That involved using six engines to do the work of five, and running six trains instead of five on roads already badly overcrowded, besides increasing the labour cost and other working expenses.

The author observed that this remarkable survival of elderly locomotives undoubtedly demonstrated the original excellence of their design and construction. American practice employs inferior materials, and builds much more roughly and rapidly, the engines not being expected nor desired to last more than ten or fifteen years. It is then preferred to replace them by new locomotives fitted with all modern improvements, and possessing a large margin of power, especially in the boiler, such power being available in case either of ordinary need or special emergency.

The author considers that it is debatable whether, on the one hand, the extreme longevity of British locomotives is desirable, involving, as it does, the crowding of the lines with old and sometimes almost obsolete locomotive types, deficient in power proportionate to modern requirements; or whether, on the other hand, American practice, while unquestionably superior in respect of providing a larger margin of power, be not defective in its results through being wasteful in coal consumption and increased cost in repairs, in consequence of inferior material being used and of a rougher mode of construction being adopted. Each plan, he observed, has its own special advantages and disadvantages.

British engines were shown to be indisputably superior to American per unit of power, but American designers provided more units of power for identical duty. These comparisons apply solely to American locomotives working in Britain or British dominions. But latterly the influence of the one feature in which American and European practice was unquestionably superior to British was seen in the vastly enhanced power, especially in the boilers, supplied to most recent British locomotives, as shown by contrast between prominent types of British locomotives in 1901 and 1902, with the leading standard types of 1895. Another result of American and European Continental influence in British practice was stated to be a tendency to multiply coupled wheels, as in the case of six-coupled wheels instead of four for passenger service, and eight instead of six for goods traffic.

Alcohol as a Motive Power.

The series of competitions and trials of alcohol as a motive power for the propulsion of cars, which was organized by the French Ministry of Agriculture, with a view of encouraging the manufacture of alcohol in France, were of a very interesting character, as was the Exhibition which followed. The results achieved, which, if perhaps unexpected,

were of a satisfactory nature, inasmuch as, whereas previously high speeds had been obtained with large and heavy vehicles, the latter were in the present case, with a single exception, surpassed by lighter carriages. The heavy-weight races for omnibuses and wagons brought out the interesting point that goods, and even passengers can be carried by alcohol traction at rates comparing very favourably with those of the railway, including collection and delivery. A further conclusion reached, is, that alcohol has been proved to be able to hold its own against petrol as far as motive power is concerned. At present, the retail price in France is just a shade higher than that of petrol; but it is probable that the cost, which has already fallen considerably, will be still further reduced. It is the use of beet-root (mangold wurtzel) in the production of alcohol, that has greatly reduced its price. In methodical cultivation, the finest roots, which show on analysis the largest proportion of sugar, are selected for seed purposes, while the remainder are cleaned, washed and sliced by machine, the juice being fermented and afterwards sophisticated so as to render it not liable to duty. This is effected by adding methylic alcohol, mixed with acetone to form methylene. About one-tenth part by weight of methylene is added to the pure spirit, together with a certain proportion of benzine, and when required it is also carburised by the addition of benzol. The consumption of alcohol per ton-kilometre was about 50 per cent. more than petrol; but, had the engines been constructed to consume alcohol instead of petrol, this difference would probably have been greatly reduced.

It is believed that the French authorities will be satisfied if the consumption of alcohol can be reduced to 30 per cent. more than petrol; in which event a great impetus will be given to the use of home-made alcohol in place of imported petrol.

In view of the increasing utility of alcohol for heating, lighting and power, and the ease with which it can be prepared from potatoes, there would appear to be a field open in Ireland, for the development of what might prove to be an important industry.

"Teon" Belting.

The opening of the new extension of the Fleetwood works of Messrs. Fleming, Birkby and Goodall, Ltd., which took place early in June, was made the occasion of demonstrating before the directors and selling agents of the company, the process of manufacture of "Teon" belting. The party was conducted over the works by the inventor of the belt, Lieut.-Col. Ash, who is also responsible for the design and arrangement of the plant.

The basis of the belt consists of a textile fabric of the highest quality and strength; this being guaranteed by the fact that should the company succeed in being able to discover a better material they have the right to cancel the contract with the makers.

The fabric is first passed through specially arranged rollers, weighing about 22 tons, in which it is thoroughly impregnated with a cement, the composition of which is a secret. The belting next undergoes the process of folding and stitching, after which it is passed through the vulcanising and stretching processes. These latter operations are performed simultaneously in special hydraulic presses, each of which is capable of dealing with 60 ft. of 13-in. belting per hour, or an equivalent length of a narrower belt. While in these machines the belt is stretched, under a pressure of 2,000 lbs. per sq. foot at boiler steam temperature, to a length equivalent to 15 ins. in every 24 ft. of belting, which renders it practically stretchless, after which it is removed to a wire stitching machine.

The whole process is one of extreme interest, and the visitors and pressmen who were privileged to see it came away greatly impressed. A series of tests were afterwards conducted with composition belts of various makes, and which were repeated by ourselves and others. The imperviousness of "Teon" belting to temperature and moisture was proved by boiling and treatment with saturated steam; whilst its general soundness could not have been better demonstrated than by the treatment in solutions of the caustic alkalis and in a strong solution of nitric acid, which left the material practically unaffected. Judging by these tests it would be difficult to controvert Colonel Ash's claim that "Teon" belting is one the strength and quality of which is of the highest order.

"Science Abstracts."

This publication, so essential to all those who are interested in the development of physics, electrical and steam engineering, now regularly deals with 150 periodicals and publications of a scientific or technical character. The more recent additions to the list include the Proceedings of various Continental scientific societies, which, in the ordinary way, are inaccessible to the British engineer. The fact that important articles often appear in such proceedings, and that abstracts of all such are published in the periodical under notice, should commend itself to those workers who do not wish to miss any important development.

REVIEWS.

***Lehrbuch der Optik* (*Treatise on Optics*).**—By Paul Drude. Leipzic: S. Hirzel. 1900. xiv. and 498 pages. Price 10 marks.

In taking up a treatise on optics from the pen of the new editor of the *Annalen der Physik*, and the author of so many valuable contributions to this important branch of knowledge, we anticipated a great intellectual treat and a method of treatment representing the high-water mark of optical theory. The best and most up-to-date English optical treatise is the work by Preston, which was published in 1895; but of Preston's 566 pages 31 only are devoted to the electro-magnetic theory, while in Professor Drude's treatise no less than 258 pages out of the 393 dealing with physical optics are occupied with the development of the general electro-magnetic theory, and the experimental verification of its consequences. This is beyond question the most important part of the work, but the earlier portions are by no means wanting both in interest and novelty of treatment. To the English reader, accustomed to the dry and disconnected disquisitions usually comprehended under the title of geometrical optics, the able and most interesting development of a systematic theory of this subject will be little less than a revelation.

On his first page the author sets forth the four fundamental laws which form the groundwork of geometrical optics, and which, as he points out, are, from the physical point of view, only approximate generalisations. These are, the rectilinear propagation of light, the independence of the component rays of luminous pencils, and the ordinary laws of reflection and refraction.

The author then develops the subject on the lines initiated by Abbe. The maximum-minimum property of the optical path of a ray through various media, of which Fermat's law of minimum time is a partial expression, is shown to follow from the fundamental laws. This leads immediately to the consideration of the aplanatic surface, and to the theorem of Malus respecting orthotomic systems of rays.

The general theory of optical images is then developed, and applied to the reflections and refractions at spherical surfaces. Astigmatic images and spherical aberration are next considered, and a demonstration given of the so-called sine law, determining the conditions of approximation under which an image can be obtained by means of a wide-angle lens, such as a microscope objective, conditions which are quite as important, and no more difficult of comprehension, than those of pencils of small angle which are discussed in the elementary text-books. The conditions of achromatism are then considered, and the reasons noted for the greatly improved results obtained by means of Schott's Jena glass, in which high refractive power is obtained in combination with low dispersion. The use of iris diaphragms is next considered, followed by a brief account of the principles of photometry and the conditions governing the brightness of optical images. A chapter explaining the principles of construction of photographic lenses, the microscope, and the telescope concludes the section dealing with geometrical optics.

The second division of the work, on "the general properties of light," treats, very much on the ordinary lines, the velocity of propagation, interference phenomena, Huyghens' principle, diffraction, and polarisation.

The principle of Huyghens and Fresnel is first developed approximately in an elementary manner after Voigt, with Schuster's corrections. This is followed by a complete demonstration. This was first given by Kirchoff in 1875, and greatly amplified in his lectures on optics published in 1891, the method there adopted and followed by Drude, with some analytical modifications of his own, consists essentially in the application of Green's theorem to the general equation for the propagation of light waves. The equation itself, which is usually deduced from the elastic solid theory of the ether, is at this stage simply assumed, as in a later portion of the work it is shown to be a consequence of the electro-magnetic theory.

The third division of the work, on "the optical properties of bodies," opens with a couple of pages on the mechanical theory, pointing out its fundamental imperfections. The author then passes on to consider the electro-magnetic theory of light first suggested by Faraday and developed by Maxwell.

This accounts naturally for the absence in light-waves of longitudinal vibrations. The boundary conditions at the surface of two media become those which hold in any electro-magnetic field, thus doing away with the fundamental defect of all the mechanical theories, and enabling the observed velocity of propagation to be calculated from purely electro-magnetic data.

The old controversy as to the plane in which the vibrations of a plane-polarised ray occur ceases to have any meaning, as there is an electric vibrarion perpendicular to the plane of polarisation and a magnetic vibration in that plane. As the two are invariably associated together, either the electric or the magnetic force may be taken as a "light-vector," determining the waves. The author prefers the former alternative as the more generally convenient, and this corresponds to the mechanical theory of Fresnel, while the other would correspond to that of Neumann and MacCullagh. The coexistence of these two sets of waves, in planes at right angles to each other and to the direction of propagation, explains why these two distinct theories both account equally well for the observed phenomena.

The general equations of the electro-magnetic field are obtained by expressing in terms of the components of the magnetic force the work, $4\pi C$, which is done in carrying a unit magnetic pole round a current C, and in terms of the components of the electric force the work done in carrying a unit charge round a magnetic flux. Poynting's theorem on the flow of energy in the electro-magnetic field is applied to show that light rays are paths of energy flow.

The optical properties of transparent isotropic bodies are next considered, and the ordinary laws of

eflection and refraction are shown to be a necessary consequence of the electro-magnetic boundary conditions, independently of the special form which these conditions may assume. This leads on to the explanation of the phenomenon of polarisation.

The production of stationary waves is explained, a phenomenon which derives a very special interest from the ingenious manner in which Lippmann has utilised it for the production of photographs in natural colours.

Passing on to the consideration of transparent crystals, since the magnetic permeability is always sensibly equal to unity, their electric properties must be determined by the dielectric constant only, and, as these properties are different in different directions, this must vary with the direction of the electric lines of force. It then follows from the general equations that the lines of electric flux do not coincide with the lines of force.

When absorption of light occurs in a body, then on the electro-magnetic theory it is not a perfect insulator, and its electrical conductivity has to be taken into account. The optical properties of iron and other strongly magnetic bodies show that even in them the magnetic permeability is sensibly equal to unity as far as luminous vibrations are concerned. The resulting modification in the electro-magnetic equations is such that the solutions can be derived from results previously obtained, in the case of bodies which are perfectly transparent to electro-magnetic radiation, simply by replacing the real dielectric constants by complex ones, the physical interpretations being arrived at in the usual manner by separating out the real and imaginary portions of the resulting formulæ. No further assumptions are required for the explanation of the phenomenon of metallic reflection.

Dispersion is considered in Chapter V., and it is shown that the only additional assumptions required for its explanation are:—that molecules or atoms of the bodies in which dispersion takes place have natural vibration periods of their own, or, as they may be called, intrinsic vibration periods; and that the molecules are built up of atoms carrying positive and negative electric charges. In a conductor these atoms must be capable of free motion of translation, while in an insulator they must have definite positions of equilibrium round which they can oscillate.

Anomalous dispersion will occur whenever the period of the light or other electro-magnetic waves is nearly equal to one of the intrinsic molecular ones. In all other cases the dispersion will be normal.

The fact that certain substances, when traversed by a plane polarised beam of light, cause a rotation of the plane of polarisation, demands the existence of asymmetric structure, either molar or molecular. The latter only is possible in fluids, and therefore the author looks to molecular structure to explain the effect in all cases.

In this connection we would point out what seems to have escaped the author's notice, that the entire disappearance of the rotational power of certain crystals on fusion shows that in their case, at any rate, the effects must be sought in aggregates of molecules, instead of in the individual molecules. The observed gradual changes in the rotational power of many newly-formed liquids points strongly in the same direction.

It should also be noted that a statically asymmetric molecular structure is not sufficient to account for rotation, for Lord Kelvin has shown that the linear equations of an ordinary elastic medium cannot include any rotational property, a statically asymmetric system being equivalent, as far as pure vibration is concerned, to its optical image. The existence of steady cyclical momenta must, therefore, necessarily be postulated, so long as we are concerned with molecules, which are so small compared with optical wave lengths, as to act, not directly, but only by sympathetic vibration.

It would be an assistance to the reader if this were clearly pointed out. The omission to do so does not, however, vitiate the mathematical argument which follows; for the author bases this on the assumption that the motion of an ion depends not only on the electric force at the place occupied by it, but also on the electric forces in the immediate neighbourhood, so that the first differentials, with respect to the co-ordinates, of the electric force components must enter into the equations. This, according to Lord Kelvin's result, implicitly involves the assumption of the existence of steady cyclical momenta. When these conditions are expressed in the most general form physically possible the resulting equations account for the observed phenomena. The author suggests that such asymmetry would be produced if the ionic paths were helices, either all right-handed or all left-handed, but with the axes disposed promiscuously; but this would make the chirality dependent entirely on the nature of individual molecules. Dispersion, both normal and anomalous, of the rotation is explained in the same manner as that occurring in refraction.

Magnetic rotation is explained by the action of a magnetic field on the molecular currents, or ionic rotations, in magnetic bodies, which will necessarily give rise to molecular asymmetry, and this will also be produced in para-magnetic bodies by the action of the field on the ionic rotations which it sets up. The Hall effect is simply the magnetic deflection of the ionic paths, and this, in conjunction with the asymmetry produced in the manner explained above, suffices for the explanation of the observed phenomenon of magnetic rotation. The Zeemann effect is fully explained on hypotheses already set forth, and the known relations between bright and dark spectral lines.

In Chapter VIII. the author discusses, following Lorentz in the main, the modification in optical conditions when the bodies considered are in motion, the ether being assumed to remain at rest, and the bodies to move freely through it.

The third and concluding division, consisting of three chapters only, deals with the radiation properties of bodies.

The work is remarkably free from typographical errors. It is also free, unfortunately, from an index, which is a serious defect in a work of such exceptional value and importance, and one which we trust will not be allowed to remain in the next edition.